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Copy of an Enlarged Negative of the Lunar Appennines. Made at the Lick Observatory, 1891, July 14. 8 hours, 12 minutes, 26.5 seconds. P. S. T.

Reduced about half for this plate.

Photograph of the Moon, made at Goodsell Observatory, June 21, 1893, with 8¼ inch Photographic Telescope and Amplifier, by A. G. SIVASLIAN.

Popular Astronomy.

Vol. I. SEPTEMBER, 1893. No. 1

CONSTELLATION STUDY.

WINSLOW UPTON.*

INTRODUCTORY.

The study of the constellations forms a very attractive part of a popular course in Astronomy. Few persons can look at the stars attentively without forming figures among them which are ever afterward associated with the stars thus grouped. The figures are frequently geometrical, such as triangles or quadrilaterals, or sometimes they are made up of groups of neighboring stars which form no special shape but which seem to be associated together. It is generally known that the ancient astronomers classified the stars in this way, and that their classification is still in use in modern times. The student therefore wisely desires to make his groupings accord with those sanctioned by tradition and accepted by the astronomers of to-day, though he may not know just what use is made of them in modern science.

The study of the constellations is too often attempted in a desultory manner. A few figures are traced and learned when in certain parts of the sky, or when seen in the direction of certain terrestrial objects, and they are not recognized under other conditions. Even the conspicuous "Dipper," which is so generally recognized when low in the northwest, is a far less familiar group when seen inverted and nearly overhead. It is quite possible for any one, who will pursue the subject faithfully and systematically, to master the leading configurations so that they will always be recognized, no matter at what time of year or in what part of the sky they may be observed; and an intelligent following of the leading groups in their apparently changing positions for a few hours of some night and for a few months in the year, will give a very clear idea of the effect which the earth's rotation on its axis and its revolution about the sun produce upon the apparent position of the stars.

It is the design of this series of articles to aid in a systematic study of the constellations. At the outset a classification will be

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given which will arrange the groups in an orderly way, and in a manner in close accord with the more modern system of designating the position of stars. Then suggestions will be offered for taking up the study in detail, by a progressive method designed to give a good knowledge of the constellations in their leading characteristics, and which can be continued to a more minute acquaintance with them as desired.

But before entering upon this subject, there are a number of preliminary statements which ought to be made, regarding the history of the classification and its present use by astronomers. In this way perhaps a clearer idea will be given of the place of constellation study in any scheme of instruction in Astronomy. For, if the truth is candidly spoken, this classification of the stars, while interesting historically, is of very minor importance in the science of Astronomy. Many professional astronomers do not use it at all, and would prefer that the system should become obsolete in whole, as it already is in part. The system is used wholly as a rough means of identifying certain of the brighter stars, and of forming certain grand divisions of the sky, much as a country is divided into states or provinces. Even this territorial subdivision is not as important as might first appear, for the system of designating stars by their positions, on the same general plan as places on the earth are designated by their latitudes and longitudes is more satisfactory as well as more accurate. But while a minor part of the science of to-day, it still has a place in it, and it possesses certain features which make it a profitable study, if not one of the highest importance.

The division of the sky into constellations is prehistoric; it seems to be the oldest part of that science which was studied in ancient Chaldea and Egypt, received and enlarged by the Greeks, and transmitted to us by the Arabians and the monastic scholars of the Middle Ages. The design of the classification was, we may believe, primarily, for identifying the stars, but it received its plan from association with the poetry and astrology of that time. Poetry gave the names to many of the groups, and allowed the fancy to pass beyond the geometrical shapes to imaginary figures of animals or other creatures, of which the stellar groups formed, as it were, the skeletons. Astrology determined some of the grosser subdivisions, such as the twelve parts of the zodiac, and gave a motive to the science, by requiring close observation in order to determine the subtle effects upon mankind which the several groups exercised. Our earliest precise knowledge of the classification is in the catalogue of the Greek astron-

omer Ptolemy, in the second century of our era. In this catalogue* are given 1028 stars, including most of the brighter stars visible in northern latitudes. They are classified in forty-eight constellations, which are all given upon modern star maps, though in a few instances the names have been changed. The positions of the stars are given by their celestial latitudes and longitudes, which is the beginning of this satisfactory method of designating their places. Each star is named by its position in the figure supposed to include the stars of the group. Thus the Constellation Draco contains thirty-one stars which are named "The star upon the tongue," "the star in the mouth," "the star above the eye," "the star upon the cheek," "the star above the head," etc. This method of naming the stars continued in use until the eighteenth century, though it was gradually supplanted by the system proposed in the seventeenth century, in which a letter or a number with the Latin genitive of the constellation was used instead of the long phrase. Thus the stars in Draco mentioned above are now designated as μ, ν, β, ξ and γ Draconis respectively.

A curious fact regarding the early division of the sky into constellations is that no attempt was made to include all the visible stars in the constellations. Apparently it was not intended that this should be a method of subdividing the visible heavens into districts, but only certain conspicuous groups were singled out, and gaps left between them. In Ptolemy's catalogue, 102 stars are given, which do not belong to any constellation; among these unclassified stars is the brilliant star Arcturus which is placed near, but not within, the constellation Boötes.

Our knowledge of the artificial figures surrounding the stellar groups is obtained from the designations of the stars themselves. It is possible to reproduce thereby the outlines of the figures with approximate accuracy, but the details of the figures cannot be given. In some cases the stars are not sufficiently numerous to allow the figure to be drawn, as in the case of the constellation Canis Minor in which but two stars are given; and in every case there is ample room for an imaginative artist to exercise his talent. It is probable too that there was no general agreement as to the groups themselves, not to mention the figures drawn about them, and if other of the early writings than Ptolemy's had been preserved, we should undoubtedly find many unexpected divergencies. Ptolemy's classification was made the basis of the

* Baily's translation in Memoirs, R. A. S., vol. XIII.

subsequent classifications of mediæval astronomers, and was materially enlarged by the addition of new groups, to fill in the gaps between those he gives. Occasional discrepancies are to be expected here also, and it is only by the arbitrary adoption of some one arrangement as authoritative, just as Ptolemy's had been adopted before, that a recognized system can be obtained. An interesting example of the uncertainty in drawing the outline figures may be found in the Atlas of Argelander, which is considered the standard authority for the northern heavens to-day. The constellation Boötes appears on two plates; in the one the figure of the hunter faces the west and his right arm holds the leashes of the hunting dogs which form the next constellation; in the other the figure faces the east, and the raised hand (in this position the left hand) holds a sickle, while the right hand, which is not shown in the other position, carries a shepherd's staff. The latter, it may be said, accords more nearly with the descriptions of the ancient catalogues, but the former is equally possible if, as is done in some atlases, the left arm rather than the right holds the leashes.

The defect in the ancient system, that the constellations did not cover the whole sky, was remedied by the addition of new constellations in the intervening spaces. As an example, the constellation Canes Venatici was added by Hevelius in the seventeenth century, to fill the gap between Boötes and Ursa Major. In so doing he built upon the traditional story of the former constellation, which was sometimes called the Bear Driver because it follows the Bear in its daily movement, and added hunting dogs. To these was due the change in drawing the figure mentioned above. But unfortunately the astronomers who engaged in this work did not work together, nor did the later astronomers adopt the suggestions of their predecessors. In the seventeenth and eighteenth centuries more than sixty new constellations were added, filling the gaps in the northern sky and continuing the system to the southern pole. Not all of these commended themselves to later astronomers, and as there was no authoritative body to decide such matters, and is none to-day, it is impossible for any one to state the exact number of constellations, much less to define their boundaries.

The astronomers of this century have been obliged to face the question what to do with the ancient system of constellations and its later additions. Some would abandon it altogether; others would retain its leading features but would simplify the subdivisions, by discarding many of the additions and straight-

ening the boundaries, but departing as little from the primitive scheme as is possible. The latter view seems to have prevailed by general consent without concerted action. The German astronomer, Argelander, whose efficient labors in cataloguing the stars about the middle of the present century gave him general recognition as an authority on such matters, incidentally performed this revision while preparing his Atlas. With but little dissent, his work is accepted as authoritative. It contains fifty-seven constellations visible in northern latitudes, which are made up of forty-six of Ptolemy's and eleven added by later astronomers, chiefly by Hevelius. Had Argelander's work been extended to the southern pole, the whole system thus revised would have been generally accepted. As it is, there is still some indecision as to the acceptance of the schemes suggested by various astronomers. The tendency is to accept only those constellations of long usage, and to limit the number as far as consistent with covering the space satisfactorily. The whole number of constellations in current use is between eighty and ninety, the exact number depending on the acceptance or rejection of minor groups in the southern sky.

From this brief account of the development of the system of constellations it will be seen that even at the present time the subject is not quite as satisfactory as might be expected. The system has been one of growth, and the growth has not always been wisely directed. As it now stands, accepted as it is by modern astronomers as an inheritance not to be lightly thrown aside, it contains some very curious characteristics. Most notable of these is the great difference in the size of the several constellations. One of these, Argo Navis, in the southern sky, is so enormous that its subdivisions into four or five parts named from the several parts of the vessel is quite commonly accepted. Another, Ursa Major, with its imposing array of bright stars, and its curious collection of pairs in close proximity, occupies a commanding space in the northern sky. Camelopardalis and Monoceros are examples of large constellations which contain but few stars visible to the naked eye—relatively blank spaces. Some of the groups, as Equuleus and Scutum Sobieski, are so small that it seems unfortunate that they were not included in the territory of their neighbors, as was done in the case of Taurus Poniatowski and some other constellations which for a time were on the accepted list. Another characteristic feature is the great diversity in the brilliancy of the different groups. This feature is of course quite to be expected, indeed no system could be devised

which would not have a like diversity because of the unequal distribution of the stars according to brightness. Another feature, however, which might have been prevented had it been desired, is the great diversity in the shape of the regions assigned to the several constellations. Snake-like figures, winding about over large areas, but leaving much adjacent territory for other constellations, seem to have beeen quite a favorite form. Draco, Serpens and Hydra are the best examples of this form, and from their shape are easily traced. In several instances constellations crossed each other, but this has been remedied by readjusting the boundaries, except in the case of Serpens which now crosses the serpent bearer Ophiuchus. Another characteristic feature is the winding of the division boundaries. This was made necessary by attempting to adhere to the original shapes of the figures as far as possible, and not to transfer stars from one constellation to another in straightening the division lines. In this way the division lines are drawn in a very meandering manner. Another evident characteristic is the slight resemblance between the stellar groups and the figures which give the names to the groups. In a few cases the resemblance is genuine; in the majority of cases no resemblance exists, and it need not be supposed, as is sometimes done, that the ancient astronomers detected such resemblance when they assigned names to the groups.

The present scientific use of the constellations is wholly for purposes of notation. There are several distinct ways in which stars are named. The earliest method, that of describing the position in the figure occupied by the star, is entirely obsolete, and the method of naming it by a letter or number followed by the Latin name of the constellation in the genitive case is used for all bright stars. The letters are usually of the Greek alphabet, and were assigned by a German astronomer, named Bayer, in the early part of the seventeenth century. The numbers are usually those assigned by the English astronomer, Flamsteed, who lived a little later than Bayer in the same century. Many of the stars have been given individual names, but with few exceptions these are nearly or quite obsolete. To take a concrete example, the bright star which is nearest the northern celestial pole was called in Ptolemy's catalogue "the star at the end of the tail"; it is known to-day in star catalogues as α Ursæ Minoris, or 1 Ursæ Minoris. It has also received the names Gjedi, Polaris, Cynosura and Alruccabah, only the second of which survives. These various methods of designating a star apply only to the few bright stars which have been catalogued for many centuries

as visible to the naked eye. All telescopic stars, and many of the fainter ones visible to the naked eye, are distinguished by their position in the sky, their right ascension (corresponding to longitude) and their declination (corresponding to latitude)—to give the technical names of the science. If a star is in any of the published catalogues of stars, it is frequently mentioned by its current number in that catalogue. Thus the pole star might be distinguished as B. A. C. 360, because it has that number in the Catalogue of the British Association. It is customary, too, in star catalogues to give the constellation within which each star comes, even if it is too faint to have a letter or a number in that constellation. Thus the use of the system of the constellations is limited to-day to the naming of the brightest stars, and these may in every case be designated without reference to the constellation, by some of the alternative methods just named. The figures have ceased to be used, but the names remain, designating now regions of the sky within which the figures were formerly drawn. The figures are not always drawn on modern star atlases, but when given in faint outline so as not to obscure the stars, they are of interest from a historical point of view, as well as frequently for their help in fixing the stellar groups themselves.

The study of the constellations has, it is true, ceased to have the prime importance in Astronomy which it possessed in former years. But it still has its merits and its interest. The professional astronomer is at a disadvantage in his technical researches who does not know the leading groups and the names or letters of the most conspicuous stars in the groups. The general student of the science also should know the important constellations, and their positions at different times of the night and the year. He will not simply gain the direct knowledge which this gives, but he will have clearer ideas of the movements of the heavenly bodies. No one who prizes the history of any science will despise a branch of it, which has indeed become of less importance in late years, but which is interwoven with the development of the science in a very marked degree.

There are other advantages in constellation study than those named, especially for the amateur or the person only casually interested in Astronomy. The stars which stud the firmament, like beacon lights in the darkness of the night, become almost like personal friends when they are recognized in their varying annual positions. The ancient Egyptians knew when the overflow of the Nile might be expected by the rising of the star Sirius

just before the Sun in the summer, and the Phœnician navigators knew when the navigation season was to commence in the spring by the corresponding rising of the group to which the Greeks gave from this circumstance the name of Pleiades. A certain constellation which rises in mid-winter in the early evening always suggests to the writer the coming of the spring. Other constellations have like associations with the different seasons. Just as in primitive times the movements of the constellations formed an infallible calendar, written upon the face of the sky, before the printed calendars were invented, so now they mark the passing seasons for those who will acquaint themselves with their forms and movements. Constellation study is also especially valuable for strengthening the power of observation and for training the memory. A casual glance at the sky leaves only a vague impression of points of light, but a closer inspection reveals the relative positions of these points of light, their varying brightness and color, their abundance in some places and their fewness in others. The fixing of the groups in the mind is by no means an easy matter, and gives therefore excellent training to the memory. The imaginative faculty is also strengthened, not so much by striving to see resemblances which do not exist, as by forming the stars into orderly groups and connecting them by lines or imaginary cords which seem to unite them into a family. All this is quite apart from the significance of the study as a beginning subject in Astronomy. As the stars must be named and grouped somehow, it is well to adopt the ancient system, whatever its defects, rather than to invent another, which lacks the associations of the old one, and which no one but the inventor would use. The outlines of the system once mastered and the leading groups learned, the less important groups may be added at pleasure and to whatever degree of refinement is desired. A good foundation is thus laid for subsequent use, and the interest excited in one branch of stellar Astronomy may lead to further studies in the same inviting subject.

"Consult with reason, reason will reply
Each lucid point which glows in yonder sky
Informs a system in the boundless space,
And fills with glory its appointed place;
With beams unborrowed brightens other skies,
And worlds to the unknown with light supplies."

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.*

1. Principles Involved in the Construction of the Instrument.

The editor of POPULAR ASTRONOMY has asked me to write a series of short articles on the spectroscope, which will be readily comprehended by those who have no previous knowledge of the subject, and which may serve as a guide to readers who have small instruments in their possession. This is the first of such a series, and the others will follow in due course. I shall hope at least to fulfil the requirement of making my meaning perfectly clear at all times, and although it will be necessary to use some technical terms in dealing with such a subject as the spectroscope, the new terms will always be explained when they are used, so that they ought to cause no difficulty to the beginner.

Few instruments assume such a variety of forms as the spectroscope. It may be a short piece of tube no larger than the eyepiece of a telescope, or it may be a large and complicated piece of apparatus filling a whole physical laboratory. To recognize the relations of instruments which differ so greatly in appearance we must understand well the principles on which they are based, while to recognize immediately the meaning of all the curious appearances seen in a spectroscope under different circumstances, requires, in addition to this, much experience in practical observation.

The chief use of the spectroscope is to study the constitution of a body by means of the light which it emits. Light is the agent which brings us the desired information, and if there is only enough of it when it reaches us, it is a matter of indifference how far it has traveled on the way. It is this independence of distance which makes the results of spectroscopic analysis seem so wonderful to one unfamiliar with its methods. Fifty years ago they were almost undreamed of. The chemical constitution of the stars, now a regular field of inquiry in many observatories, was once mentioned by an eminent metaphysician as an example of the knowledge which must remain forever beyond our reach. If our sense of admiration is blunted by custom, let us try to imagine what a philosopher of the last century would have said, if the results of modern spectroscopic analysis had been laid before him, without any explanation of the way in which they had been obtained.

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To illustrate the principle of the spectroscope, let us consider some simple experiment, in which we shall not be confused by a complexity of apparatus. Perhaps the best one will be the historic experiment of Newton, which, indeed, every beginner should repeat. We first, then, make a hole, say half an inch in diameter, in the shutter of a darkened room, so that a beam of sunlight enters the apartment and falls upon the floor. Next we take a glass prism, which for this purpose need not be a very good one, —a prism from a chandelier will answer, if it has a considerable angle,—and hold it in the path of the beam, with the sharp edge downward. The beam of light is immediately bent upward, out of its original direction, and on the opposite wall of the room appears a beautiful rainbow-tinted band, red at the lower and violet at the upper end. To this colored band of light Newton gave the name of spectrum.

White light, therefore, is made up of light of many different colors, which Newton roughly designated as red, orange, yellow, green, blue, indigo and violet, but the colors blend into each other so that the number of shades is really infinite. We shall see that the different kinds of light separated by the prism differ in other properties as well as in color.

The solar spectrum obtained in this experiment, although beautiful enough to the eye, is what is technically called an "impure" one; that is, the different kinds of light are not perfectly separated on the screen, but overlap and are confused. To obtain a pure spectrum we must employ somewhat more elaborate apparatus; still the spectrum which we have is good enough to illustrate many points of the greatest importance in practical spectroscopy, and we shall use it for this purpose before going further.

The beam of light which comes through the hole in the window shutter is bent out of its course, or *deviated*, by the prism, and it is evident that the colors are separated because the blue light is more deviated than the red. The separation of the colors is called *dispersion*, and like the deviation, is measured in degrees. Thus, if the deviation of red light is 50° and that of violet light 54°, the spectrum will be 4° long, and the prism is said to have a dispersion of 4° between the red and the violet parts of the spectrum. If the reader will refer to an elementary text-book on physics, he will find that the action of a prism is due to the fact that light travels more slowly in glass than in air, and that the violet rays are more retarded by glass than the red rays.

Now let us experiment by rotating the prism about its lower

edge, or refracting angle. We shall find that no matter how we turn the prism, we cannot make the deviation of any given part of the spectrum *less* than a certain amount, called the minimum deviation. When the prism is in the position which produces minimum deviation the light enters and leaves the prism equally inclined to its two surfaces.

Starting from this position of the prism, let us turn it so that the light falls more directly on the first face. The spectrum is thrown higher on the wall and at the same time it is lengthened; the dispersion is increased. If we turn the prism in the opposite direction the deviation will also increase, but the spectrum will shorten, *i. e.*, the dispersion will be diminished.

In the spectroscope, the prism is almost invariably used in the position of minimum deviation, but it is sometimes an advantage to know how to vary the dispersion by the simple method just described.

A technical term much used in spectroscopic literature is "monochromatic" light, and we may illustrate its meaning with the apparatus which we are supposed to have before us. The meaning, according to the construction of the word, is light of a single color, but color is here used in a stricter sense than in ordinary language. The light transmitted by red glass, or the red of the rose, is not by any means monochromatic.

If we receive the spectrum from the prism on a screen, and make a small hole in the screen so as to let through a beam of, say, red light, we obtain a beam of light which is approximately monochromatic. It is not perfectly so, on account of the overlapping colors on the screen, and because the hole is of considerable size, but if we imagine the spectrum to be very pure and the hole extremely small, we can form an idea of what is meant by monochromatic light. Such a beam would be refracted by a prism placed in its path, and changed in direction, but it would not be dispersed like a beam of white light.

It is not an easy matter to obtain really monochromatic light, but for all ordinary experiments a spirit lamp, in the wick of which a little salt has been placed, gives a flame which will answer quite well. The flame really radiates two slightly different kinds of yellow light, so nearly alike that no eye could distinguish their difference in color, and there is also some blue and green light from the alcohol flame, but these rays are quite faint. Professor Michelson has shown that certain red rays from burning cadmium are almost ideally monochromatic.

Let us now consider a somewhat more elaborate optical ar-

rangement, which will give a pure spectrum, and which, carried out practically in glass and metal, will rise to the dignity of being called a spectroscope.

I must assume that the reader is familiar with the ordinary properties of lenses, for it is hardly possible to go back to first principles in every branch of our subject. If he has not this knowledge, he should by all means acquire it by reading the proper part of an elementary text-book of physics. I will however mention the principal property of a convex lens, which at once finds an application in constructing our new apparatus. If parallel rays of light fall upon a convex lens, they will be converged to a point on the other side called the principal focus, and conversely, if a luminous point is placed in the principal focus of a convex lens, those rays which fall upon the lens will emerge parallel.

Fig. 1

Let *A* (fig. 1) be a point emitting monochromatic light, which we may suppose to be yellow, and let it be in the principal focus of the convex lens *C*; then the rays emerging from *C* will be parallel. Let *D* be another similar convex lens, placed in the path of these rays. By this lens the parallel rays will be converged to a point *B* in its principal focus, and this point is an image of *A*. A single lens could be employed to produce the same result, but then in no part of the system should we have parallel rays, the use of which will soon be apparent.

Perhaps I should say here that the image *B* is not really a point, even if the lenses are perfect, but an extremely minute disc, surrounded by fine rings of light. The reader who has used a telescope is familiar with the appearance described, for it is that of every star image. For our purposes *B* may be regarded as a point, although the fact that it is really a very small disc is of great importance in the complete theory of the spectroscope.

Light diverging from a point just below *A* would be converged to a point above *B* and equally distant from it. Every point near *A* has its corresponding point near *B*, and thus an image of any object placed at *A* is formed at *B*. The image is of the same size as the object, and it is inverted. The luminous object might be the salt (or sodium) flame already referred to, and then an inverted image of the flame would be thrown on a screen held at *B*.

Now let us suppose that a glass prism is placed between the lenses where the yellow rays from the point *A* are parallel, as in fig. 2. If the first surface of the prism is flat, all the parallel rays from *C* meet it at the same angle, and they will all be refracted, or bent by the same amount on entering the glass, if the glass is homogeneous, or of the same refracting power in every part; the rays will therefore still be parallel in passing through the prism. If the second surface is also flat, all the rays will again be equally refracted toward the base of the prism, and they will pass out with their parallelism undisturbed, although in quite a different direction from that of entering. Passing through the lens *D* the rays are converged to a point *V* in its principal focus, as before. We may turn the prism until *V* is displaced as little as possible from its original position *B*, and in the figure the prism is shown in this position of minimum deviation.

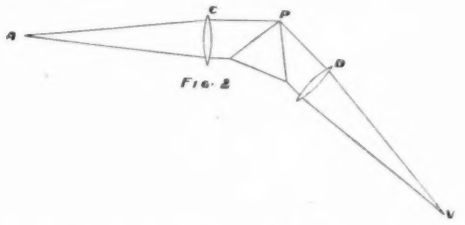

FIG. 2

If with the prism so adjusted, we place a sodium flame at *A*, we shall obtain an image of it at *V*, precisely similar in every respect to the image when there was no prism, as in fig. 1.

If we suppose *A* in fig. 2 to be a point emitting *red* monochromatic light instead of yellow, then the course of the rays will be the same as before, *except* that the red rays being less deviated by the prism, the red image or point in the focus of *D* will be formed higher up, nearer to the place it would have in the arrangement shown in fig. 1.

Now let us suppose the point *A* to emit both red and yellow monochromatic light (and nothing else). Until they fall on the prism, both kinds of light pursue the same course, but by the prism they are separated. On leaving the prism all the yellow rays are parallel to themselves, and all the red rays are parallel, but the two sets of parallel rays are travelling in slightly different directions, and when they pass through the lens *D* the yellow rays are converged to a point *V* and the red rays to another point *R* (fig. 3) above the first. If *A* is a *flame* emitting the same two kinds of light, then we shall get a yellow image of the flame

at *V* and a red image at *R*, alike except in color, and both of the same size as the flame itself. The apparatus serves to analyze the light, and shows that the flame emits two distinct species of rays, which could not be recognized by the unaided eye.

As both images of the flame are quite large, it is probable that they will overlap, and not be entirely separated. We may, however, cover up the sides of the flame, and prevent their light from entering the apparatus. The images will then be formed of the uncovered part of the flame, and will be narrower. If, for instance, we make a round hole in a card, and place the hole exactly at *A*, with the flame close to it on the outside, each image will consist of a round disc of light. Perhaps the images still overlap on their nearest sides. We make a smaller hole in the card, and now the images, being smaller, are completely separated. Whatever shape we choose to give the aperture in the card, the images will have exactly the same shape.

Now remembering that the images are always exactly like the aperture, and that their centers are always the same distance apart, let us consider what form of aperture it will be most advantageous to use. It is evident that the greatest amount of light will be admitted, with the greatest possible separation of images, if the aperture is a very narrow rectangle, with its longest side parallel to the refracting edge of the prism. The images will of course be equally narrow rectangles. If the aperture is very narrow we may call it a slit, and the images will then be mere lines of light, parallel to each other and to the edge of the prism. Now these two images constitute the spectrum of the flame, and in spectroscopic parlance it would be said that the spectrum of the flame consisted of two bright lines, one in the yellow and one in the red. *Lines* are always mentioned in describing a spectrum simply because the aperture which admits the light is always a *slit*.

It is important to observe that altering the width of the slit does not change the brightness of the lines,—merely their width.

A monochromatic blue flame placed in front of the slit would give a blue line in the spectrum, considerably further from the red than the yellow line, but in the same direction from it; and finally a flame which, like that of a candle, gives out all kinds of light, would give a spectrum consisting of a continuous band of color without interruptions of any kind, like the solar spectrum of our first experiment. The images of the slit, being infinite in number, blend together to form what is called a continuous spectrum. We shall see later what the solar spectrum is like with our new apparatus.

The spectra obtained with this apparatus are pure, for each kind of monochromatic light gives one, and only one bright line in the spectrum. At the same time there is a limit to the purity which can be obtained with it, for the slit must have *some* width, and we can imagine two kinds of monochromatic light so nearly alike that the two images of the slit would overlap, even with the narrowest slit that it would be practicable to use.

It remains now to show how the optical parts which we have considered are put into practical shape, so as to form a spectroscope.

The lens *C*, which in practice is an achromatic lens, and not a simple one as shown in the figure, is mounted in one end of a tube, and the aperture or slit is placed at the other. The slit is however attached directly to a shorter tube which slides in the first, so that by pushing it in or out it can be adjusted exactly in the principal focus of the lens. Sometimes a focusing screw is added to make the adjustment easier. The width of the slit is varied by turning a small screw. The whole tube carrying the lens and slit is called the collimator.

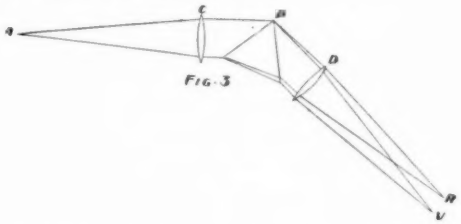

FIG. 3

The prism is placed on a little table, and in a good instrument it should rest on three small foot screws, so that its edge can be made vertical.

The lens *D* which should also be achromatic, is mounted in one end of a tube. The images which it forms are not thrown on a screen, but viewed directly by a magnifying glass, or eyepiece, placed at the other end of the tube just beyond the point *B*. A short sliding tube, like that in which the slit is mounted, enables the eyepiece to be pushed in or out, so that the spectrum may be seen distinctly. The whole tube therefore forms a small telesope, and the three parts now described—collimator (with slit), prism, and telescope,—are the essential parts of the ordinary and most generally useful form of spectroscope.

If the spectrum is very short and the eyepiece large, the whole spectrum may perhaps be seen at once, and then the telescope

can be fastened in a position determined by trial; but it is much better to have it movable about a center under the prism, and then it can be brought in line with the collimator as in fig. 1, or turned so as to bring any desired part of the spectum to the center of the field of the eyepiece.

Next time I shall tell how to use a spectroscope of this form, and describe the solar spectrum as seen with it or any other instrument of small dispersion. I have dwelt at some length on the principles involved in its construction, but not, I think, more than their importance requires, for it is absolutely necessary that they should be thoroughly understood before proceeding to more complicated arrangements, and to the wonderful results which have followed the application of the spectroscope to astronomy.

THE MOON.

WM. W. PAYNE.*

A series of articles will be prepared for this magazine to show, in a general way, what is known about the Moon, the sources of information, something about the unsettled questions and the theories pertaining to them, and, at the proper time, a *résumé* of the discussion now going on in relation to the decay and possible dissolution of satellites generally.

In the study of the Moon writers generally begin with a description of its motions, figure and dimensions, then notice its physical features and, from its singular and varied formations infer its condition and physical constitution. From a study of its surface markings is obtained nearly all that is known, at present, about the Moon.

It will be very profitable for the reader to notice, in the outset, that this knowledge, in even its easy and elemental parts, was gained only by careful, persistent and long continued observation of such surface markings as could be revealed plainly to the unaided human eye. Those who have read any lunar history belonging to very early times will remember that very little useful knowledge was acquired by Chinese, Hindoo or Egyptian astronomers because they did not observe or work systematically. The Chinese probably made the earliest record of a lunar eclipse, 2158 B. C., but the account of it contains scarcely more than a mere mention of the event, while those of the Egyptians and Hindoos are said to be vague and even less complete. On the other hand,

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the Chaldeans appear to have made and recorded regular series of observations, from a very early period, although only those of later time have been preserved, as far as we now know. Ptolemy gives these later records commencing with the lunar eclipse of 720-719 B. C. As might be expected the Chaldeans were rewarded in the results of their work because it was done regularly, carefully and thoroughly. Instances of this are seen in the fact that they were able to find the length of the solar year, as 365¼ days, that they knew very closely the time of the Moon's revolution and that they should be able, from a very long series of observations of eclipses to determine the Saros, a period after which eclipses follow one another again, in the same order for another like period of time, and, on account of which coming eclipses could be predicted with considerable accuracy.

About a century later (650 B. C.) another important feature marks the progress of astronomical science. Greek philosophers introduced into the study of astronomy their own purely theoretical ways of thinking, so that from the time of Thales to Aristotle comparatively little observing was done; they were, however, very busy in constructing theories, mainly concerning the markings of the lunar surface and the resemblances between the Moon and the Earth, but their theories varied greatly at different times and in different schools of the philosophers. However it is pleasant to notice that Aristotle* (382-322 B. C.) taught that the Moon, on account of its phases and eclipses, must be a sphere always turning the same face to the Earth, and that it is nearer than the planet Mars because the former is known to occult the latter. The Greeks had knowledge of the Chaldean Saros and tried to improve it by better Cycles of their own, the most important of which was called the Metonic Cycle (432 B. C.) by Meton, an Athenian. This Cycle consisted of 6940 days (about 19 years) the error of which for the Sun was nine hours, for the Moon seven hours, with a difference for the two bodies of only two hours. The advantages of this Cycle were many and early astronomers held it in high honor, and its successive years were publicly designated by numbers in gold, hence the so-called golden number of the Metonic Cycle. In 330 B. C., Calippus improved this Cycle by multiplying it by four and subtracting one day, which made the new period to consist of 27,759 days (about 76 years), consisting of 940 lunations, making, at its end, a nearer coincidence of the Sun, Moon and seasons than the Saros; for, by this, not only was the order of the eclipses known, but

* Neisen's The Moon, page 81.

also the day on which particular ones came could be predicted for years to come. This Cycle was adopted by scientific astronomers of this period. In the year 320 B. C., began the use of better astronomical instruments and more systematic work in observing' though it should be borne in mind, that the time of which we now speak was nearly 2000 years before the invention of the telescope, it was also the beginning of the period of Aristarchus, Hipparchus and Ptolemy whose skillful work will have full notice in due time.

At 140 A. D. begins a period of fourteen centuries during which there was very little improvement in Astronomy, as may be illustrated by the fact that the lunar theory remained just where Ptolemy left it for all those centuries. When Tycho Brahe (1575 –1600 A. D.) began his work of exact observation, which was soon followed by Gallileo with the wonderful discoveries of the first telescope, the era of modern Astronomy began, in which the study of the Moon would naturally lead.

It will be the purpose of this series of brief papers to give an outline of lunar history arranged by topics and dates for convenience in reference, to present the methods of study used in early times, to compare the work by the naked eye and that done by the aid of the telescope, showing the use of the opera glass, the small telescope and the great instruments of the present time, to point out what celestial photography can do to reveal minute details of structure in the formations on the lunar surface, to give some knowledge of the amount of light and heat from the Moon, with illustrations showing how the instrument, called the bolometer, detects variations of temperature in the surface and its relation to light-phase, and, finally, to refer to such evidence as science gives on the question of its habitability by beings like ourselves in view of its present physical condition and possible state of dissolution suggested in the beginning of this paper. The illustrations belonging to this theme will be the best in kind and quality that can be secured, and we believe they will be a source of interest to the reader that could not possibly be awakened by any other means. They will have the accuracy of photography and all the clear detail needed for exact instruction. Those given in this number are intended for illustrations, and are not meant to be closely related to any particular points in this introductory paper.

THE ASTEROIDS AND THEIR RELATION TO THE PLANETARY SYSTEM.

DANIEL KIRKWOOD.

At the beginning of the nineteenth century a new field of research was opened to astronomers. A class of bodies till then unseen by human eye, and unimagined by the human mind; a class, indefinite in numbers—perhaps more difficult to enumerate than the stars as seen without a telescope; a celestial cluster, in short, within our own solar domain, was first revealed to telescopic view. To trace the progress of research in this zone of minor planets; to mark the conquests already achieved, and to inquire whether the time has yet come to co-ordinate the facts now known, is the principal aim of the paper which follows.

The name *asteroids* was given by Sir William Herschel to the telescopic planets found moving in the space between the orbits of Mars and Jupiter. The term *planetoids* is preferred by some writers, and *minor planets*, by others; the name given by Herschel, however, seems likely to be permanent.

Astronomical, as well as mathematical discoveries are sometimes prophetic. In other words, they give promise of other and still greater discoveries to follow. When the first asteroid was revealed to view, on the first night of the century, the fortunate Piazzi but little dreamed of the prospect which he had opened to astronomers. Our solar system as then known consisted of twenty-three planets, primary and secondary; it now contains over three hundred and eighty; of which more than three hundred and fifty are asteroids. The number to be added in another century is yet unknown. The progress of astronomical discovery, however, is not limited by the number or volume of the bodies revealed. This is eminently true of the planetary cluster now to be considered. What does it indicate in regard to the physical history of planets, or the laws by which the heavenly bodies are controlled? As elsewhere remarked, "if the universe is a book written for man's reading," only patient study may resolve the problem contained in these mysterious leaves.

From the time of the far-seeing Kepler till near the close of the eighteenth century, the thought of a missing or undiscovered planet was permitted to slumber; but when, in 1781, Sir William Herschel brought Uranus to light, and when it had been shown that its distance fell into the series of Titius, or Bode, the idea was again revived. It was in fact supposed to be realized in the

discovery of Piazzi's telescopic planet. What then was the surprise of astronomers when within six years the harmony was again destroyed by the detection of three more, Pallas, Juno, and Vesta? The result was the hypothesis proposed by Olbers to account for the phenomena. *Small* asteroids were not looked for by that astronomer, and their discovery was therefore suspended for thirty-eight years.

The search for minor planets was next resumed about 1831, by Herr Hencke, of Driesson. Success was first reached in 1845, and from this date laborers were numerous and discoveries frequent. About forty planet-hunters entered the lists, and the following numbers are now (1893) attached to the names of the most successful.

Discoverers.	Asteroids.	Discoverers.	Asteroids.
Palisa	85	Watson	22
Peters	45	Borelly	17
Charlois	28	Goldschmidt	14
Luther	24	Hind	10

Of the 352 members now known (1893), 270 have been discovered in Europe, 76 in America, and 6 in Asia. Seven has been about the average yearly number from 1845 to 1893. All the larger asteroids of the zone have doubtless been discovered. It seems not improbable, however, that an indefinite number of very small bodies belonging to the zone remain to be found. Photography is becoming an efficient means of discovery.

Laplace knew only of the first four minor planets—nothing of the wide spread swarm of hundreds composing the zone. Astronomers, however, who adopted his views on the origin of the system looked to the nebular hypothesis as the early history of the related planets. But between 1845 and 1853 more than twenty new members were added to the cluster. Within the same time, and before the invention of the spectroscope, it was announced that the nebula in Orion had been resolved by Lord Rosse's telescope. This startling claim—not sustained by later observations—was the signal for abandoning the nebular hypothesis by many of its former advocates. To others, however, the resolution of a nebula, even if confirmed, seemed hardly a sufficient reason for the theory's rejection. The question arose whether any probable test of Laplace's hypothesis could be found in the solar system itself. The train of thought was somewhat as follows: Several new members have been found in the zone of asteroids; its dimensions have been greatly extended, so that we can now assign no definite limit either to the ring itself

or to the number of its planets; if the nebular hypothesis be true, the Sun, after Jupiter's separation, contracted successively to the various decreasing distances of the several asteroids; the eccentricities of these bodies are generally greater than those of the old planets; this difference is probably due, in some way, to the disturbing force of Jupiter; the zone includes several distances at which the peroids would be commensurable with that of Jupiter; in such case the conjunctions of the minor with the major planet would occur in the same parts of its path, and the disturbing effects would accumulate. We have thus a natural field for extraordinary perturbation. Can we still trace the creative plan in these works around us? Or has time been able to obliterate it in the long cycles of the past?

Not explosion but tidal action may have been Nature's ancient mode of separation.

The similarity between the elements of certain asteroids began to be noticed by the present writer about 1867; being first referred to in Meteoric Astronomy.* "A comparison of the elements of Clytea and Frigga," the author there remarks, "shows a striking similarity; and Professor Lespiault has pointed out a corresponding likeness between the orbits of Fides and Maia. For these four asteroids the nodal lines and also the inclinations are nearly the same; while the periods differ by only a few days. It is probable, therefore, that they are all fragments of the same narrow ring." The subject, however, though still occasionally noticed, received no special study for a number of years. The author's monograph on the Asteroids was published in 1887. On pp. 47 and 48 of that work the phenomena were again referred to; the writer specifying several marked instances of agreement in distance, motion, direction, etc. It was finally concluded that in view of the facts presented, the division of tenuous, primitive masses seemed certainly less improbable than the accidental coincidence of so many elements. The cause, of whatever nature, which has separated cometary masses in our own day, may have been operative also in the original condition of the minor planets. The fact—which might be shown as one of almost infinite improbability—that precisely where the inclinations, eccentricities, etc., are most nearly coincident, there also the orbits are most closely contiguous, seems capable of physical explanation on the theory of a common origin in the nebular hypothesis.

The author's first paper on this subject, read, in part, before

* Page 110.

the Astronomical Society of the Pacific, February 10, 1890,* and concluded March, 1891, contains ten binary and ten ternary asteroids. Subsequently, M. Tisserand, of the Institute of France, independently noticed a number of these striking coincidences and unhesitatingly remarked that they "cannot be accidental." Mr. W. H. S. Monck also in the *Sidereal Messenger* called attention to the phenomena in October, 1888, stating that "their number is far too great to be explained by chance."

CONCERTED OBSERVATION OF THE AURORA.

M. A. VEEDER.

There has grown up in connection with studies in which the writer has been engaged a system of observation of the aurora which permits comparisons to be made between records from different stations. This plan has been in operation for several years and has gradually extended until, in connection with the Arctic observations undertaken by Lieut. Peary in very high latitudes, it has received such an impulse as promises to insure extremely valuable results. Observers are coöperating in pretty much every part of the Earth where auroras are seen at all, and in some localities those coöperating are sufficiently numerous and so distributed as to permit comparisons to be instituted in reference to what appear to be local peculiarities of displays. The most paradoxical and mysterious feature thus far encountered is the evidence that has occasionally been received which seems to indicate that an aurora may be visible at stations southward in the usual location looking towards the north, and at the same instant observers further north on the same meridian may record the sky as entirely clear and free from any appearance of the aurora whatever, whether toward the north or south. What seems to have been a notable instance of this kind occurred on the night of July 15th. The observer at Ottawa, Canada, reported that the sky became entirely free from traces of the aurora at 11:55 P. M. At the same instant at several stations southward in the vicinity of Lake Ontario the northern heavens were still full of flashings and flickerings together with considerable diffused auroral luminosity. Only eight minutes later at three of these stations, namely, Toronto, Sodus and Lyons, an auroral curtain with sharply defined lower margin was seen advancing from the north west leav-

* The first paper published on the subject, so far as I know.

ing perfectly clear sky underneath. Unfortunately there is as yet no report from stations northward at this exact instant, but it seems almost certain that this curtain had moved southward, leaving clear sky in its wake, and that it became entirely invisible soon after passing the zenith of the places of observation. In other words, it could be seen towards the north but not towards the south. Its lower margin formed such a prominent land mark in the sky and gave such evidence of parallax that it is quite certain that the altitude of this margin at 12:05 A. M. was not far from twenty miles above the south half of Lake Ontario.

This is adduced as an instance of the very puzzling peculiarities in the behavior of the aurora which it is extremely desirable to explain if possible by systematic, concerted observations. The same night there was another feature not so difficult of explanation but none the less interesting. At stations in the vicinity of Lake Ontario from 10:00 to 10:30 P. M. there was seen a narrow auroral band which is generally described by those who saw it at its first formation, as extending at that time from a point on the horizon north of west eastward just south of the zenith towards a point on the south eastern horizon. This being the case, this band could not have been either perpendicular or parallel to the true magnetic meridians of the places of observation, but must have conformed to a temporary magnetic system developed at the instant and having its own set of meridians, thus corresponding to the behavior of the magnetic needle which deviates from its usual position at such times in order to conform to the new system temporarily induced. So far as is known to the writer, the deviations of auroral arches and streamers from their ordinary positions relative to the magnetic meridians of the places of observation is a phase of the subject that had never so much as been thought of until the present system of observations was undertaken.

Another very important question is as to what it is in certain localities that attracts the aurora. It has been thought that Archaen rock and the mineral constituents of the soil have this effect. Perhaps this may be so, but in looking over the records that have been obtained by concerted observation the writer has been struck by the fact that auroras seem to be much more numerous and brighter in localities where the Coast Survey maps show that the magnetic meridians are much displaced. This bending and twisting of these meridians is most apparent along the courses of great streams flowing east and west, like the St.

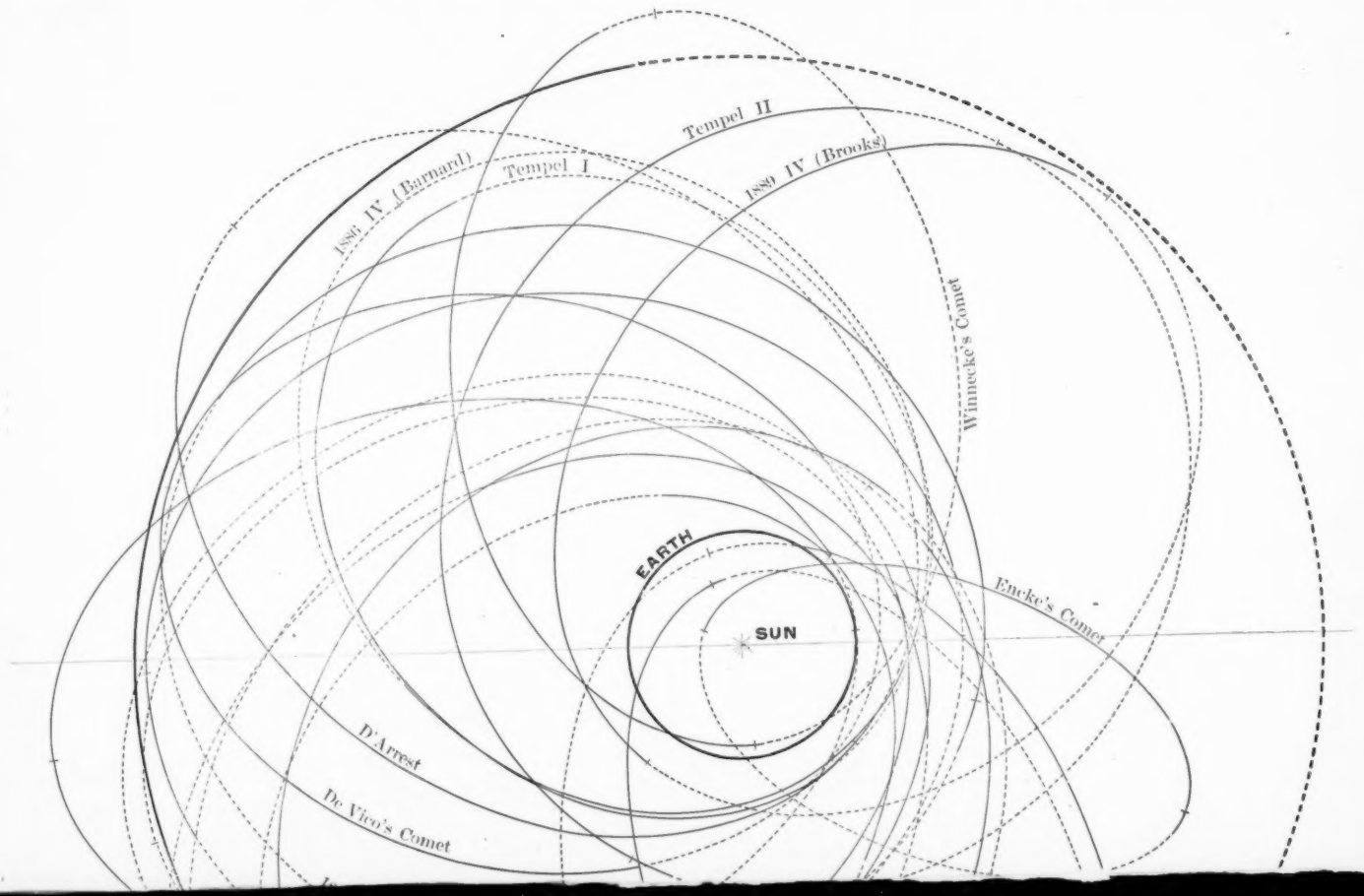
Lawrence, the Ohio and the Missouri. It has been thought that the motion of the streams carrying along mineral particles in suspension may have a modifying inductive effect locally, and may thus become responsible for the unstable state of magnetic equilibrium in these localities which is favorable for the development of the aurora. If this should prove to be the true explanation, it would follow that the arrangement of the magnetic system of the globe as a whole might depend to an important extent upon ocean currents, and even to some extent upon air currents. It is one of the features with reference to which concerted and systematic observations are most desirable, opening up as it does a new field in which pioneer work is to be done.

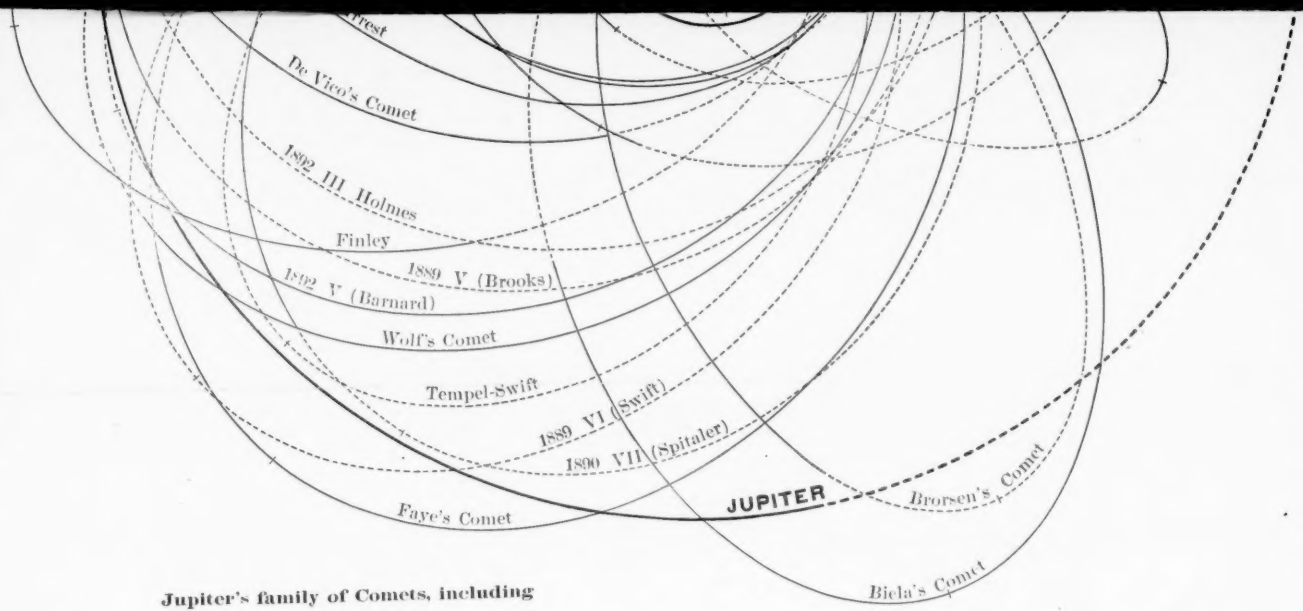
These are some of the problems involved which have been held in reserve so far as public announcement heretofore is concerned. The questions concerning the relation to specific solar conditions, and to atmospheric electrical conditions have already been put forth, and some of the conclusions respecting these questions that appear to be justified by the system of observations that has been inaugurated have been announced and are being discussed quite generally. So far as the writer is able to determine, electro-magnetic induction of solar origin depends upon what bears every mark of being volcanic activity at certain points on the Sun, and is propagated from the Sun outward throughout the Solar system dynamically, or, in other words, in definite relation to the motion of rotation. This is the root principle of the whole matter, and its various ramifications require to be traced out and confirmed by proper systematic observation, and may eventually be found to be of most far reaching and serious consequence.

It is evident that this is a class of observations to which non-professional as well as professionel students of natural phenomena may contribute materially. So far as the writer is concerned it has grown out of studies which were originally undertaken as a matter of amusement, but which have grown more and more serious as the importance of their consequences has been recognized, and an insight into the nature of the problems involved has been gained. It certainly is a most fascinating and may prove eventually to be a most fruitful field of research.

Lyons, N. Y., Aug. 10, 1893.

PLATE III.


Tempel II
1889 IV (Brooks)
1886 IV (Barnard)
Tempel I
Winnecke's Comet
EARTH
SUN
Encke's Comet
D'Arrest
De Vico's Comet



Jupiter's family of Comets, including Holmes' Comet.

From a drawing by A. G. Sivastian, Northfield, Minn.

Goodsell Observatory, Carleton College.

JUPITER'S COMET FAMILY.

WM. W. PAYNE.

As we have not seen anywhere a full illustration of Jupiter's comet family, as now known, we venture to give one in the accompanying large plate. This is called Jupiter's family of comets because they all seem to be, in some way, related to this great planet. Other large planets likewise have comet families. But this one is by far the largest of those known in the solar system. It consists of nineteen members varying in known historical age from more than 100 years down, if we say Encke's is oldest, and the Holmes' of 1892 is the youngest.

The line through the middle of the plate is the line of the equinoxes and the position of the vernal equinox is at the right hand end of the line and the autumnal at the left. The top of the plate is 90° of longitude and the bottom is, of course, 270°. The Earth's orbit is a solid ring because it lies in the plane of the ecliptic. All other orbits are broken because they are inclined to the ecliptic. The dotted portions are below the ecliptic *i. e.* towards the south pole of the heavens, while the continuous parts of these paths are above or north of the ecliptic. Now, notice some curious facts:

1. That nearly all the farthest points of these comet orbits from the Sun (aphelion) are on one side of Jupiter's orbit. The points are generally marked by short cross-lines.

2. Notice where the dotted portions of the orbits join the continuous ones; when the comets respectively are at these points, they are nearly in the plane of Jupiter's orbit, and all of them quite near his path, so that the influence of the planet on the comets must have been considerable when so near one another.

3. The Sun and the whole solar system is moving through space towards a point in the Constellation of Hercules, having right ascension of 267° and declination north 31°. Now, notice that the bottom of the plate is right ascension (or longitude) 270° and that direction is the way the solar system and all belonging are drifting in space at a probable rate of 16 miles per second continually. If Jupiter obtained his family by capture, why should he be more successful on one side of his orbit than on the other?

4. The motions of these bodies about the Sun are direct the same as the planets, *i. e.*, contrary to that of the hands of a watch. Jupiter's orbital velocity is 8 miles per second, hence on

one side of his orbit he is moving in space at the rate of more than 20 miles per second, while on the other, it would be about eight. Probably Jupiter will meet or overtake more comets and influence their courses at the former rate than at the latter, especially if we think of comets generally moving through space in any direction, and at the distance of Jupiter from the Sun, as having an average velocity of eleven miles per second.

5. The periods of revolution around the Sun of these comets is from three to eight years, being about one half of Jupiter's period around the Sun.

These are some of the reasons that have led astronomers to think that Jupiter has obtained his family of comets by capture on account of his great attractive force when they happened to come near enough to him to be under his control largely. If one should pass within 3,000,000 of miles of Jupiter, his attraction would exceed that of the Sun, and the comet might then possibly revolve like a Moon, though this is not at all probable, from the nature of the comet generally, nor is there such a known case in astronomy.

It should also be said that some prominent astronomers (notably Mr. Proctor), do not believe in the "capture" theory. We think the weight of opinion is in its favor. In 1884, Mr. Proctor advocated strongly that the origin of comets belonging to the solar system was from the Sun by ejection, also possibly from the larger planets in their process of development from the nebulous state. More will be said about these comet families at another time.

ASTRONOMY WITH THE SMALL CAMERA.

H. C. WILSON.

One of the simplest experiments for the amateur is that of photographing star trails. For this only the ordinary mounting of the camera is necessary, as the camera remains fixed during the whole exposure. The ray of starlight falling on the sensitive plate does not remain in the same position, but trails across the plate, producing an impression which on development is shown as a fine line of greater or less width and density according to the brightness of the star. If the camera is directed toward the celestial equator these star trails are nearly straight lines, but in other positions they are more or less curved. Near the pole

they are arcs of small circles, which would be completed if the exposure could be continued for twenty-four hours. One of the most pleasing lantern views, and one which affords a striking illustration of the rotation of the Earth, may be made from a negative of the polar sky. The exposure for this purpose should be of at least an hour's duration.

The work of photographing star-trails is not only adapted to give pleasure to the amateur and his friends but also may be of scientific value. It is possible to determine from the width and density of the trails the relative brightness of the stars. There is here therefore a means of studying the fluctuations of variable stars and of discovering new stars. Of course with a small camera this would be limited to the brighter naked-eye stars, for only these would leave their trails upon the plate. There is also always the possibility of a meteor crossing the field of view and leaving a permanent record of its appearance, as was the case with the very interesting photograph obtained on Jan. 13, 1893, by Mr. John E. Lewis of Ansonia, Ct. (A reproduction from the original negative appeared in the *Photographic Times*, Feb. 3, 1893, and a fine enlarged photogravure is to appear in the September number of the *American Journal of Science*).

If one wishes to obtain pictures of the sky including as many as possible of the fainter stars, his camera must be rigidly attached to an axis parallel to the Earth's axis and turned by accurate clock-work. A very practical way is to fasten the camera to a telescope which is provided with a driving clock, as many of the telescopes owned by amateurs now are, and use the telescope for guiding the camera. Even if the driving clock be a poor one, the observer can, by patient watching correct the irregularities of motion by means of the slow motion screws of the telescope, and obtain perfect pictures with exposures of even several hours' duration.

The telescope should have an eyepiece of moderate power containing rather coarse cross-wires. A bright star thrown a very little out of focus will enable one to see the wires without any other illumination, so that the star may be quite easily kept bisected by the cross-wires. One of the wires should be placed parallel to the diurnal motion of the star so that if, by any accident or sudden irregularity of the clock, the star should leave the intersection, it may still be upon the parallel wire and be easily brought back to the intersection.

In this way the observer, looking at one star in the telescope and keeping it at the intersection of the cross-wires, causes the

rays of each star in the field of view of the camera to continually fall upon the same spot upon the sensitive plate. The star images are thus formed round and thousands of faint stars are enabled by the prolonged exposure to produce impressions which are capable of development.

The ordinary form of camera with bellows and rack motion is not suitable for this work. The plate holder and objective should be rigidly connected, so that the changing position of the camera may produce no perceptible flexure. The best form is perhaps that of a rectangular box of light wood which may be conveniently strapped or fastened with brackets to the telescope tube. A cylindrical steel tube would perhaps be better were it not for its weight. The lenses should be mounted in a sliding tube so that the focusing may be done by pushing them in or out instead of moving the plate holder. There should also for this purpose be a fine scale on the sliding tube, so that for any picture the scale reading may be recorded. Then when the best focus has been found the scale may always be set at the proper reading.

The best focus must be found by experiment. It will not be very far from the visual focus. The best way will be to focus as nearly as possible with the stars or Moon on the ground glass, then draw the objective out a little, say one millimeter. Turn the camera toward the polar sky and make it stationary. Expose for five minutes; move the objective in a little, say two tenths of a millimeter; expose for five minutes again; move the objective in the same distance as before; expose again and so on until eight or ten exposures have been made at different readings of the focusing scale, all without altering the position of the camera. When the plate is developed the star trails will be found to be broken into as many divisions as there were exposures made. Some one of these divisions for each star will be found to be blacker and narrower than the others. The corresponding scale reading will represent the focus for that star. It will not be the same for stars in all parts of the field. That should be selected which will give the best definition over the largest portion of the plate without sacrificing the central part.

A number of very interesting photographs have been obtained at Goodsell Observatory with Darlot combination of lenses of 2½ inches aperture and about 7 inches back-focus. The plate accompanying this article gives copies by photogravure of the original negatives. In that of the constellation Orion the principal stars will be easily recognized. The great nebula is shown in

the centre of the plate. Just above it is the nebula about c Orionis, which seems almost to be a part of the great nebula. A little higher up the three stars, ζ, ε and δ of the belt of Orion are readily recognized. The curious nebula about ζ which was first discovered by photography is plainly shown. On the original negative this nebula seems to extend over the whole belt and downward to the left past the great nebula around ϑ Orionis, beyond the star ν, then makes a great loop to the left and extends upward and to the right as far as the comet-like flaw in the upper part of the plate. The greater part of this enormous extension is so extremely faint that it is doubtful whether it will appear in the photogravure. The hundreds of fainter stars about the belt are many of them, just below the limit of naked eye vision but can be seen with a good opera-glass. Down toward the right is Rigel, surrounded by a large ring. The ring is due to halation or reflection of the light which was so bright as to penetrate through the film to the back of the glass plate. This effect may be avoided by using the nonhalation plates which are now in the market. This picture was taken on the night of Jan. 25, 1892, with an exposure of 3 hours. A beautiful picture of the great nebula of Orion was taken at the same time with the 8-inch photographic telescope to which the camera was attached. The two were guided by the aid of a second telescope through which the observer looked at the brightest star in the trapezium in the nebula and kept it constantly bisected by a pair of cross-wires.

The second picture is of one of the bright patches of the Milky Way, put down on the maps as *Scutum Sobiesii.* The little spot in the center is the splendid telescopic cluster which we all enjoy looking at so much. By the aid of a microscope one may distinguish some of the stars of the cluster. In this picture it is very evident that the light of the Milky Way results from that of a great number of stars which are just beyond the limit of naked-eye vision. Examined closely under the microscope, the whole background of the picture is in places filled with minute stars, while in others, it appears blank. One cannot help being struck by the arrangement of stars in curved lines in many places. This picture was taken Aug. 18, 1893, with an exposure of $1^h\ 50^m$.

In both pictures it will be noticed that the stars, though round at the center, are elongated toward the edges of the plate. This is because the lenses were made for short distance work. With lenses especially constructed for stellar work, good images should be formed over the whole plate.

Mr. J. A. Brashear, of Allegheny City, Pa., is now constructing a stellar camera for Goodsell Observatory. It is to have a combination of four lenses of six inches aperture and the distance from the inner lens to the plate will be 31 inches. Dr. C. S. Hastings calculated the curves of the lenses to suit the particular glass used. It is expected that the definition will be good over the whole of a 10×10 plate, which will take in an area of sky over 15° square. We hope before long to let the readers of POPULAR ASTRONOMY see some of the work done by this new camera.

SUGGESTIONS TO AMATEURS.

NEBULÆ AND COMET SEEKING.

LEWIS SWIFT.

With this initial chapter I assume the task of preparation of a monthly series of papers on these and other allied subjects for the new candidate for public favor, the forthcoming POPULAR ASTRONOMY. I undertake this with the understanding that my articles shall be written in as untechnical language as possible, being for the entertainment and instruction of amateur astronomers only, whose observations are limited to the use of telescopes of from three inches to six inches of aperture. It is, perhaps, needless to say that the effort is made a little difficult by reason of the query of how well the objects described will answer the illustrations when seen with the varying instruments—larger or smaller—under different atmospheric conditions, and with practiced or unpracticed eyes.

The number and variety of objects under the head of nebulæ and clusters, found in greater or less profusion in every portion of the sky, is very great, aggregating nearly eight thousand, but of these only a few will come into the list of those within easy, scrutinizing reach of small glasses. As, however, many possessors of such instruments indulge in the pleasant pastime of comet-seeking, some with considerable persistence, it is quite important that the places of all comet-appearing nebulæ be known with, at least, a tolerable degree of exactness, that the observer may arrive at an immediate decision whether the suspect be a comet or not, at which juncture a catalogue of such nebulæ is indispensable, saving all loss of time not only, but preventing the annoyance to himself and others of false notification of the dis-

covery of a comet (of which many have come to me), which, though improbable, I have not thought it right or wise to withhold from general telegraphic announcement when cloudy skies prevented its verification here.

A case in point is the recent finding and immediate telegraphic information to me of the discovery of a naked-eye comet by Mr. Alfred Rordame of Salt Lake City, Utah.

That his claim to priority of discovery may be understood by astronomers and also by the committee of award of the Donohue comet medal, I take, herewith, the opportunity to reproduce his dispatch *verbatim* as received by me at 4 o'clock on the morning of July 9. "Salt Lake City, Utah, July 8; to Lewis Swift. Warner Observatory, Rochester, N. Y. Naked-eye comet; observed 10 o'clock, constellation Lynx; no telescopic observation possible. Alfred Rordame." I had reasonable doubt as to the reality of his find as I had thoroughly searched that region of the heavens but two evenings previous, but still deemed it rash to keep back its transmission and, therefore, telegraphed it to Professor Pickering with the caution "Verify" before it should be cabled abroad.

I am thus particular in transcription and detail because two young men of Alta, Iowa, claim to have seen it on the same evening at 9^h 30^m, which, with the hour's difference of time in their favor, would give them priority of discovery by 1½ hours. Had they made immediate telegraphic notification of the fact to some astronomer they could clearly have received the honor and the medal which will, under existing circumstances, no doubt, now be conferred upon Mr. Rordame. This recital will, I trust, suggest promptness of action in the event of discovery.

Now, when an amateur astronomer, possessing no catalogue of nebulæ, picks up a faint, nebulous object, how is he to determine with the necessary promptitude whether it be a comet or a nebula? Four principal methods are available to the professional astronomer but only the latter two of these to the amateur, viz:

1. Often a first glimpse will decide, a comet, to the practiced eye, appearing unlike any nebula.

2. An absolute knowledge that no nebula is there, which fact not many amateurs could know.

3. Visibility of a tail almost always opposite the Sun.

4 Detection of motion, which, if ascertained beyond a doubt, is a sure sign. This in the case of a rapidly moving comet, may, with a proper appliance in the eyepiece, generally be detected in a few minutes, though often an hour and even longer time is re-

quisite for absolute certainty in this and for the rate of its motion. Though the object move but a hair's breadth, yet that is sufficient to prove it a comet, but here, under the stress of excitement, the eye often plays false. Several stars may, commonly, be seen in the field, many times two in one direction and other two in another, which will range with either the center or some part of the visible surface of the supposed comet. In a little while a very little motion will be suspected when, in all probability, it has not moved at all. To guard against this deception of the eye, I long ago placed in front of the center of the field lens of the eyepiece, a positive (Ramsden), a single horse hair which the luminosity of the sky renders visible without artificial illumination. The eyepiece when rotated will quickly find two stars in each of two directions that the hair (in astronomical parlance termed the wire) will bisect with the object. By this means, a very trifle of motion will declare itself, using, of course, the same comparison stars for each observation. In this manner, there being no opportunity for eye deception, the least motion imaginable and its direction may be estimated with considerable accuracy. If the eyepiece be a negative (Huyghenian) the hair must be attached to the diaphragm between the lenses.

A worker among the nebulæ may chance upon a comet at the outset of his career, or he may seek months and even years and no comet reward his quest, yet for many there is a seductive charm in the work, especially in the study of the resolvable clusters which continually renews enthusiasm and inspires noble and holy thoughts.

In the succeeding numbers of this series, it is my design to illustrate the objects discussed as viewed with my 4½-inch comet-seeker.

WARNER OBSERVATORY,
Rochester, N. Y., Aug. 1, 1893.

A LESSON ON HARVEST MOON.

ELIZA A. BOWEN.

"The full Moon that comes nearest to the autumnal equinox" (coming in 1892 on September 25) "is known as the Harvest Moon: the one next following, as the Hunter's Moon. At that time of the year, the Moon while nearly full, rises for several consecutive nights at nearly the same hour, so that the moonlight

evenings last for an unusually long time." The foregoing is Professor C. A. Young's account of Harvest Moon.

Some very simple observations can be made at the time of Harvest Moon which enable us easily to understand its cause. By noting every evening the point of the horizon at which the Moon rises, it becomes evident that the Moon's position is changing northward rapidly.

The Moon rises because the Earth's rotation on its axis brings the horizon down to the Moon; the Moon rises later on consecutive evenings, because she herself revolves round the Earth in the same direction in which the Earth rotates, and having changed place during the rotation of the horizon, it must rotate a little further to overtake her. But the facts stated above show that in September the full moon travels in her orbit, not directly east, but northeast. A path or line directly east from the horizon would be perpendicular to the horizon, a northeast line must be oblique to the horizon.

The September full Moon is traveling on the part of her orbit most oblique to the horizon. It is evident that the moon traveling away from a line will increase its distance from the line more rapidly the more her path approaches a perpendicular. In September, her path being very oblique, she does not get far ahead of the horizon, and consequently the horizon loses little time in overtaking her and the Moon rises nearly at the same hour on consecutive evenings.

In order to secure genuine activity of the student's mind in teaching this, it is best to develop the subject by a series of questions after the Socratic manner. I give an example below.

Is the Sun's rising due to the Sun's motion? What moves? When you say that "the Moon rises," what moves? What line in nature does the rising Moon seem to pass above? Is it the Moon or the horizon that moves? In what direction does the horizon move? Is the Moon wholly at rest, or has she also some motion of her own? In what direction does the Moon revolve round the Earth? Do the horizon rotating with the Earth, and the Moon revolving round the Earth, move in the same or in opposite directions? Would the horizon find the Moon in the same position at the beginning and end of a rotation? Would the Moon at the end, be in advance of her position at the beginning, or behind it? Would the Moon overtake the horizon on consecutive evenings sooner or later? Why then does the Moon rise later every evening?

If the full Moon in September is found further north on every successive evening, can her path lie directly east from the horizon? Since she is found a little further north, and a little further east every evening, what must be the direction of her path in September? Would a northeast line drawn from the horizon be perpendicular or oblique to the horizon? Does the September full Moon move, then, on a path oblique or perpendicular to the horizon?

The student should now draw a horizontal line to represent the eastern horizon. From it he should draw a perpendicular and an oblique line both extending downwards. Then he should take a linear measure of one inch to represent the distance traveled during the twenty-four hours occupied by the horizon in making one rotation. He should begin at the junction of the lines with the horizon, and measure off this distance on both the perpendicular and the oblique line. We may then ask:

On which path, the perpendicular or the oblique, would the Moon reach the greatest distance from the horizon in twenty-four hours? Would the horizon catch up with the Moon sooner when she is traveling on a path perpendicular, or on one oblique to the horizon? Would the Moon rise sooner when traveling on a path oblique or on one perpendicular to the horizon? Why does the full Moon in September rise nearly at the same hour on consecutive nights? What do you see in nature showing that the full Moon in September moves on a path oblique to the horizon?

In practice, it would probably be found necessary to add other questions.

One very great advantage in this method of explaining Harvest Moon is, that the student can at any time of the year, in a class room or anywhere, *visualize* the facts in nature on which the explanation depends. To visualize is to represent in the imagination, to see with the mind's eye. When the proper time comes for seeing what has been visualized by description, he is almost certain to be inspired with a desire to see it.

This visualizing can be carried to a much greater extent in teaching elementary astronomy, and is of great importance. It keeps the student in touch with nature.

SHOOTING STARS.

How to Observe them and What they Teach us.

W. F. DENNING.*

Chapter I. General Remarks.

A very pretty incident, inseparable from the contemplation of the heavens, is afforded by the unexpected and silent flight of a shooting star. On a clear moonless night we cannot view the firmament for any length of time before one of these fugitive sparks will suddenly emerge out of the darkness and, dashing along a considerable space, will then as quickly disappear, leaving the observer in astonishment at the brevity of the spectacle and puzzling how to account for it. Everyone must naturally have

* Bishopston, Bristol, England.

had an experience of this kind and it is one which impresses itself upon the memory. When the observer is alone and the beauty of a starlit sky tempts him to gaze upwards the sudden incursion of a luminous object so utterly dissimilar to the rest, is a little apt to prove startling, besides involving a mystery which sets him thinking. Is it that a distant orb has changed its place in the firmament? Has it lost its stability and hurled itself upon destruction? Or does it simply represent an electric spark or an atmospheric phenomenon originated by the combustion of gases evolved from the Earth? May it not have been a sort of celestial *ignis fatuus* of unhappy omen? Questions like these are often suggested to casual observers of shooting stars, and it is fortunate that they are capable of being answered on the basis of observed truths. The uninformed have sometimes thought that in the momentary gleam of a falling star they have witnessed the death of a world, but science has shown that the event has no such significance.

In the course of these papers we hope to indicate the method of observation usually pursued in recording shooting stars, and we may also have an opportunity of glancing at some of the leading facts in our knowledge of these remarkable bodies. They are not always referred to under the same title, for we find them variously called "shooting stars," "falling stars," "meteors," "meteorolites," "meteorites," etc., but the terms may be regarded as synonymous.

For many generations shooting stars were regarded as atmospheric appearances, not reducible to any well defined laws. Their irregularities and brief existence gave the idea that the study of them would not be productive of any useful lessons and they were entirely neglected. No one seems to have recognized that these bodies possessed a degree of importance far beyond what their visible character implied. It is perhaps a little singular that ancient astronomers did not pay more attention to them, because they form a class of objects eminently suited for naked-eye observation and one on which they might have exercised their patience with much success.

Detached notices of meteors are, it is true, sometimes met with in old writings, but these are general ones and contain nothing but exaggerated outlines of the events observed. Thus in Plutarch's Life of Julius Cæsar it is stated that before the battle between Cæsar and Pompey, "as Cæsar walked the rounds at midnight there appeared a luminous phenomenon in the air like a torch which, as it passed over his camp, flamed out with great

brightness and seemed to fall in that of Pompey." It is obvious that descriptions of this character, though interesting to the ordinary reader of history, possess no scientific value.

It may be justly said, even to-day, that there is no branch of astronomy which promises to unfold more significant and wide-reaching facts than that dealing with meteors. Nor is there any description of objects more universal in their operations or more plentiful in numbers than are to be found in meteoric astronomy. Perhaps also we may be safe in saying there is no department of the science capable of furnishing a richer harvest of observations to the persevering student. Large numbers of new showers await discovery, and there are important features relating to some of the oldest and best known systems which have never yet been adequately investigated. Meteors abundantly pervade every region of the Earth's orbit and they probably infest all space in an endless variety of grouping and orbit.

It cannot be too forcibly impressed upon intending observers that the utmost precision in recording meteors is imperative to the value of the results. Professor Herschel has truly said that "great accuracy in observation alone affords the key to the solution of the problem presented by meteors in their nightly flights." These statements may possibly be thought a little inconsistent, for everyone must realize that as the work depends merely on eye estimations it is impossible to eliminate errors; in fact the nature of the research does not admit of absolute accuracy. But there is no doubt that with great care and with the aptitude acquired by long practice a degree of exactness may be ensured that would scarcely have been thought possible in the face of the difficulties to be encountered. These can, however, be successfully overcome by the observer of experience whose eye is well trained to the work, and whose just conception and appreciation of the details enables him to utilize them with advantage.

Before an observer may be considered thoroughly proficient he requires many months of habitual work in watching and registering meteor paths. It is quite impossible for anyone to secure reliable results, except in special cases, until properly qualified in the light of experience. And this department is one where "personal equation" must operate in a considerable degree. One observer, though he may have had no more practice than another, will attain far greater accuracy. It depends in a great measure upon natural ability. We can only look for the best results where this ability and thorough practice are combined.

For the reason that first attempts are generally untrustworthy

young observers are recommended not to be premature in the publication of results. It is far better to wait and to feel one's way cautiously. Old observers have sometimes regretted that their early enthusiasm prompted them to record results which failed to stand the tests applied in after years.

Though for many centuries the proper observation of these bodies was neglected, men at length were led to recognize the importance of submitting them to systematic study. But the early observers appear to have been content to record their general positions and directions relatively to the points of the compass. Heis, at length, about 50 years ago, saw the necessity of being more precise and began to register the apparent astronomical positions of their paths amongst the stars. He was followed and imitated by Schmidt and in recent years observers generally have adhered to the same excellent plan. It is certainly far more precise than the indefinite method of our forefathers and its adoption has directly led to the discovery of many important facts concerning meteors.

In this department the observer has not necessarily to wait certain times and seasons, for the fall of meteors is uninterrupted during the year though subject to decided variations. The summer and autumn months are the most prolific in these bodies while a comparative scarcity prevails in the winter and spring. The morning hours are the best in which to look for them, as at this period they are generally about twice as numerous as they are before midnight.

If we attentively watch the heavens for two or three hours on a fine autumn evening, we shall certainly notice many of these shooting stars, and it will soon become apparent that individually they offer some wide distinctions. They show no uniformity in their directions, positions, magnitudes or motions, in fact variety appears to be a leading characteristic. Their discursive flights across the celestial vault would seem to suggest nothing of order amongst them but that they are dispersed indiscriminately. Some of the meteors shoot across the sky with great velocity and lines of phosphorescence are generated along their paths. They are so quickly gone that the eye retains but a very hurried impression of their appearance. Others move with comparative slowness and we are enabled to follow them steadily and to watch their disappearance in a stream of sparks. And it will be remarked that a small proportion of the meteors shoot upwards so that the designation "a falling star" is not always strictly expressive of the effect observed. In brightness too a

singular diversity will become obvious. Small meteors, which the eye can but just distinguish, are seen alternately with far brighter objects, and a difference of color is also very striking in many instances. Amid all this dissimilarity and apparent confusion, it would appear impossible to introduce anything like order, but in our next paper we shall hope to show that the complication is really not so intricate as it seems, but that we may readily classify the meteors according to their motions and appearances, and reduce them to well defined systems.

THE FACE OF THE SKY.

The following statements of the appearance of the sky are true for Northfield, Minnesota, at 9 o'clock, Sept. 25th. These statements will be equally serviceable on other nights if it be remembered that for each preceding evening four minutes should be added to the time, and that for each succeeding evening four minutes should be subtracted.

Facing the north, we see to the west the familiar Big Dipper, standing with its base to the horizon, and its handle pointing toward the brilliant Arcturus just disappearing below the horizon (an hour earlier this beautiful star can be better seen): the second star in the handle is a good naked-eye double. Still facing north, we see Cassiopea's chair or the "w" as some prefer to call it. In this region we note a star cluster which to the unaided eye appears as a nebulous spot in the sky; the opera glass resolves it into a beautiful cluster; it may be located by using as pointers γ and δ of Cassiopea (the first star in the back and the one next it in the seat of the chair), following the line of these stars away from the constellation for a space about three times their distance apart, we find the patch of haze. Still to the east and much higher in the heavens is the great Square of Pegasus: Cassiopea is about half way between the northern horizon and the constellation; a line from the northern point of the horizon through the seat of the chair passes through the square. It is possible by the aid of this constellation to locate an important point in the heavens, the Autumnal Equinox, a point which no bright stars mark; by following the line of δ and γ (the two eastern stars of the square) for a distance equal to the distance between them, we come to a point which, if not the exact position of the equinox, is very near to it. Now taking a line from this point through the pole we have the position of the great circle known as the Equinoctial Colure.

Facing the south, Sagittarius is seen disappearing below the western horizon. Much higher in the heavens and about an hour and a half past the meridian is a noticeable line of three stars in the constellation Aquila, the bright Altair in the middle and a fainter star on either side; passing from the lowest of these stars in a south-westerly direction for a distance about equal to the length of the line of three, we come to η of Aquila, an interesting variable star which changes from 3rd to 5th magnitude in a period of 7½ days; during this time it makes four distinct changes of brightness. To the east of Aquila is the little diamond of four stars known as Job's Coffin. Still higher in the heavens is the brilliant, blue Vega (α Lyræ which twelve thousand years hence will be the pole star). Two faint stars near Vega make with it a little equilateral triangle; the farther north of

these is ε Lyræ, a difficult naked-eye double; an opera glass brings out the two companions beautifully, while a large telescope shows that each of these is itself double. It is thought that the two stars seen in the opera glass revolve about their common center in something like a million years, and that the stars of each of the lesser pairs are revolving about their respective centers—the one in a period of about two thousand years and the other in half that time.

61 Cygni is a star of much interest in that it is the nearest of all stars visible in our latitude, the nearest and yet believed to be 366,400 times as far from us as is the Sun—a distance over which light travels in 6 years; it is a 5th magnitude star just crossing the meridian, and six degrees south of the zenith; it makes a little right triangle with two somewhat brighter stars.

The point toward which the solar system is moving at a rate, (according to latest authority,) of 14¼ miles a second, is in the constellation Hercules. This point, known as the "Apex of the Sun's way," is very nearly in a line with the two stars, ε Lyræ and Vega; to locate it, follow this line from ε through Vega about seven times their distance apart. Very near the apex are two fourth-magnitude stars, and not far away is one of the third magnitude.

The Milky Way may prove an unending source of interest and profit to the naked-eye observer as truly as to the possessor of a small glass. To the careful, patient observer on moonless nights its extent and interesting detail seem ever increasing. An opera-glass will resolve many of its hazy patches into star clusters of great beauty.

Later issues of POPULAR ASTROMOMY will present star charts to aid in tracing constellations.

PLANET NOTES.

Mercury is morning planet during the first part of September, but rises too near the Sun to be visible to the naked eye. On the 20th Mercury will be at superior conjunction. Toward the end of October the planet will become visible in the evening twilight, just after sunset.

Venus is the bright "evening star" which is so noticeable in the west after sunset at this time. The motions of the Earth and Venus are so related now that Venus appears to recede very slowly from the Sun, and will not be in very favorable position for observation until the latter part of October. Venus will be in conjunction with the Moon, 30′ north, Sept. 12 at $11^h\ 19^m$ P. M., central time, and again, 1° 49′ north, Oct. 13, $6^h\ 40^m$ A. M. On Oct. 12, at $8^h\ 39^m$ P. M., the star δ Scorpii will be seen in the same field of the telescope with Venus, the star being 13′ south of the planet.

Mars will be in conjunction with the Sun Sept. 4 and will not be visible during the following month.

Jupiter is now a very brilliant object in the morning sky. During September and October Jupiter will be in most excellent position for observation, especially during the latter half of the night. The planet is in the constellation Taurus between the Pleiades and Hyades, and is moving very slowly. It is now moving easward, will be stationary Sept. 19, and after that will retrograde slowly. Jupiter will be in conjunction with the Moon Sept. 2 at noon, Sept. 29 at $6^h\ 31^m$ P. M., and again Oct. 26 at $11^h\ 12^m$ P. M., central time. At all of these conjunctions the Moon will pass from 4° to 5° north of Jupiter.

Saturn will be at conjunction with the Sun Oct. 8, and will therefore be invisible during the months of September and October.

Uranus will be too low in the west in the evening to be well seen. He will be in conjunction with the Moon 2° 14′ north, Sept. 14 at 12^h 55^m A. M., and again 2° 24′ north, Oct. 11 at noon.

Neptune will be at quadrature, 90° west of the Sun on Sept. 5. The position is very favorable for observation especially after midnight. It is in Taurus about 14° east of Jupiter, about 2° west and 32′ south of the 5th magnitude star τ Tauri. On Sept. 15 Neptune will be at the stationary point of his apparent path among the stars and will be very nearly in the same place during the two months of September and October.

Planet Tables.

MERCURY.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5	10 11.5	+ 12 49	4 17 A. M.	11 11.4 A. M.	6 05 P. M.
15	11 22.5	+ 5 56	5 17 "	11 42.8 "	6 09 "
25	12 28.1	− 1 56	6 14 "	12 08.9 P. M.	6 04 "
Oct. 5	13 28.3	− 9 21	7 04 "	12 29.7 "	5 55 "
15	14 25.8	− 15 46	7 50 "	12 47.8 "	5 46 "
25	15 21.7	− 20 47	8 29 "	1 04.1 "	5 39 "

VENUS.

Sept. 5	13 01.9	− 6 16	8 24 A. M.	2 01.3 P. M.	7 39 P. M.
15	13 46.2	− 11 13	8 49 "	2 06.2 "	7 21 "
25	14 31.7	− 15 46	9 14 "	2 12.2 "	7 10 "
Oct. 5	15 18.8	− 19 43	9 40 "	2 19.9 "	7 10 "
15	16 07.6	− 22 53	10 04 "	2 29.2 "	6 54 "
25	16 57.8	− 25 04	10 26 "	2 39.9 "	6 54 "

MARS.

Sept. 5	10 56.2	+ 7 57	5 24 A. M.	11 58.3 A. M.	6 32 P. M.
15	11 19.8	+ 5 26	5 19 "	11 42.5 "	6 06 "
25	11 43.4	+ 2 53	5 13 "	11 26.7 "	5 40 "
Oct. 5	12 07.0	+ 0 16	5 07 "	11 10.9 "	5 14 "
15	12 30.7	− 2 23	5 02 "	10 55.3 "	4 48 "
25	12 54.5	− 4 56	4 57 "	10 39.7 "	4 23 "

JUPITER.

Sept. 5	3 57.0	+ 19 22	9 30 P. M.	4 53.9 A. M.	12 17 P. M.
15	3 58.2	+ 19 24	8 52 "	4 15.8 "	11 39 A. M.
25	3 58.0	+ 19 22	8 13 "	3 36.3 "	11 00 "
Oct. 5	3 56.4	+ 19 17	7 32 "	2 55 4 "	10 18 "
15	3 53.5	+ 19 08	6 51 "	2 13.2 "	9 35 "
25	3 49.5	+ 18 55	6 09 "	1 29.9 "	8 51 "

SATURN.

Sept. 5	12 47.1	− 2 36	7 54 A. M.	1 46.6 P. M.	7 39 P. M.
15	12 51.4	− 3 04	7 21 "	1 11.5 "	7 02 "
25	12 55.8	− 3 32	6 48 "	12 36.5 "	6 25 "
Oct. 5	13 00.0	− 3 59	6 15 "	12 01.7 "	5 48 "
15	13 04.3	− 4 26	5 42 "	11 26.9 A. M.	5 12 "
25	13 08.8	− 4 53	5 09 "	10 52.1 "	4 35 "

URANUS.

Sept. 5	14 22.3	− 13 44	10 15 A. M.	3 21.5 P. M.	8 28 P. M
15	14 24.1	− 13 53	9 38 "	2 44.0 "	7 50 "
25	14 26.0	− 14 03	9 01 "	2 06.6 "	7 12 "
Oct. 5	14 28.2	− 14 14	8 25 "	1 29.6 "	6 34 "
15	14 30.5	− 14 25	7 48 "	12 52.5 "	5 56 "
25	14 32.9	− 14 37	7 12 "	12 15.5 "	5 19 "

NEPTUNE.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5.....	4 49.4	+ 20 55	10 16 P. M.	5 46.1 A. M.	1 17 P. M.
15.....	4 49.5	+ 20 55	9 36 "	5 06.9 "	12 38 "
25.....	4 49.4	+ 20 55	8 57 "	4 27.5 "	11 58 "
Oct. 5.....	4 49.0	+ 20 54	8 17 "	3 47.8 "	11 19 "
15.....	4 48.4	+ 20 52	7 38 "	3 07.9 "	10 38 "
25.....	4 47.7	+ 20 51	6 58 "	2 27.9 "	9 58 "

THE SUN.

Sept. 5.....	10 58.6	+ 6 33	5 29 A. M.	11 58.4 A. M.	6 28 P. M.
15.....	11 34.6	+ 2 45	5 41 "	11 54.9 "	6 09 "
25.....	12 10.5	− 1 09	5 52 "	11 51.4 "	5 50 "
Oct. 5.....	12 46.7	− 5 02	6 04 "	11 48.2 "	5 32 "
15.....	13 23.6	− 8 48	6 17 "	11 45.7 "	5 14 "
25.....	14 01.6	− 12 22	6 30 "	11 44.1 "	4 58 "

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

Sept. 4	9 P. M.
9	8 "
14	8 "
19	8 "
24	7 "
29	7 "
Oct. 4	7 "
9	6 "
12	6 A. M.
14	6 P. M.
17	6 A. M.
19	6 P. M.
22	6 A. M.
27	6 "

ALGOL.

R. A.....$3^h\ 1^m\ 1^s$
Decl.....$+40°\ 32'$
Period.....$2d\ 40^h\ 49^m$

Sept. 15	3 A. M.
17	midn.
20	9 P. M.
23	6 "
Oct. 5	5 A. M.
8	2 "
Oct. 10	11 P. M.
13	8 "
28	4 A. M.
30	midn.

λ TAURI.

R. A.....$3^h\ 54^m\ 35^s$
Decl.....$+12°\ 11'$
Period.....$3d\ 22^h\ 52^m$

Oct. 18	6 A. M.
22	5 "
26	3 A. M.
30	2 "

R. CANIS MAJORIS

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$-16°\ 11'$
Period.....$1d\ 3^h\ 16^m$

Sept. 1	4 A. M.
9	3 "
16	6 "
17	2 "
18	5 "
26	4 "
27	7 "
Oct. 4	3 "
5	6 "
12	2 "
14	5 "
21	4 "
Oct. 22	7 A. M.
29	3 "
30	6 "

U CORONÆ.

R. A.....$15^h\ 13^m\ 43^s$
Decl.....$+32°\ 03'$
Period.....$2d\ 10^h\ 51^m$

Sept. 8	midn.
15	10 P. M.
22	7 "
Oct. 23	9 "
30	7 "

U OPHIUCHI.

R. A.....$20^h\ 47^m\ 40^s$
Decl.....$+34°\ 15'$
Period.....$1d\ 11^h\ 57^m$

Sept. 1	10 P. M.
2	6 "
6	10 "
7	6 "
11	11 "
12	7 "
17	8 "

U OPHIUCHI, CONT.

22	8 "
27	9 "
Oct. 2	10 "
3	6 "
7	11 "
Oct. 8	7 P. M.
13	8 "
18	8 "
23	9 "
29	10 "
30	6 "

Y CYGNI

R. A.....$20^h\ 47^m\ 40^s$
Decl.....$+34°\ 15'$
Period.....$1d\ 11^h\ 57^m$

Sept. 2	3 A. M.
5	3 "
8	3 "
11	3 "
14	3 "
17	3 "
20	3 "
23	2 "
26	2 "
29	2 "
Oct. 2	2 "
5	2 "
8	2 "
11	2 "
14	2 "
17	2 "
20	2 "
23	2 "
26	1 "
29	1 "

Phenomena of Jupiter's Satellites.

	h	m				
Sept.	1	12	28	A. M.	II	Ec. Re.
		12	58	"	II	Oc. Dis.
		3	15	"	II	Oc. Re.
	2	9	23	P. M.	II	Tr. Eg.
	3	4	00	A. M.	I	Sh. In.
	4	1	11	"	I	Ec. Dis.
		10	29	P. M.	I	Sh. In.
		11	50	"	I	Tr. In.
	5	12	41	A. M.	I	Sh. Eg.
		2	01	"	I	Tr. Eg.
		11	09	P. M.	I	Oc. Re.
	7	3	06	A. M.	III	Ec. Dis.
	8	12	51	"	II	Ec. Dis.
		3	05	"	II	Ec. Re.
		3	30	"	II	Oc. Dis.
	9	9	18	P. M.	II	Sh. Eg.
		9	37	"	II	Tr. In.
		11	53	"	II	Tr. Eg.
	10	10	42	"	III	Tr. In.
	11	12	02	A. M.	III	Tr. Eg.
		3	05	"	I	Ec. Dis.
	12	12	22	"	I	Sh. In.
		1	41	"	I	Tr. In.
		2	35	"	I	Sh. Eg.
		3	52	"	I	Tr. Eg.
		9	33	P. M.	I	Ec. Dis.
	13	1	00	A. M.	I	Oc. Re.
		9	03	P. M.	I	Sh. Eg.
		10	20	"	I	Tr. Eg.
	15	3	27	A. M.	II	Ec. Dis.
	16	9	33	P. M.	II	Sh. In.
		11	54	"	II	Sh. Eg.
	17	12	06	A. M.	II	Tr. In.
		2	21	"	II	Tr. Eg.
		9	13	P. M.	III	Sh. In.
		10	57	"	III	Sh. Eg.
	18	2	28	A. M.	III	Tr. In.
		3	46	"	III	Tr. Eg.
		9	28	P. M.	II	Oc. Re.
	19	2	17	A. M.	I	Sh. In.
		3	31	"	I	Tr. In.
		11	27	P. M.	I	Ec. Dis.
	20	2	50	A. M.	I	Oc. Re.
		8	45	P. M.	I	Sh. In.
		9	58	"	I	Tr. In.
		10	57	"	I	Sh. Eg.
	21	12	09	A. M.	I	Tr. Eg.
		9	17	P. M.	I	Oc. Re.
	24	12	09	A. M.	II	Sh. In.
		2	30	"	II	Sh. Eg.
		2	32	"	II	Tr. In.
	25	1	13	"	III	Sh. In.
		2	57	"	III	Eg. Sh.
		9	34	P. M.	II	Ec. Re.
		9	38	"	II	Oc. Dis.
		11	53	"	II	Oc. Re.
	26	4	11	A. M.	I	Sh. In.
	27	1	21	"	I	Ec. Dis.
		10	39	P. M.	I	Sh. In.
		11	47	"	I	Tr. In.
	28	12	51	A. M.	I	Sh. Eg.
		1	58	"	I	Tr. Eg.

	h	m				
Sept	28	9	00	P. M.	III	Oc. Re.
		11	06	"	I	Oc. Re.
Oct.	1	2	45	A. M.	II	Sh. In.
	2	9	55	P. M.	II	Ec. Dis.
	3	2	15	A. M.	II	Oc. Re.
	4	8	23	P. M.	II	Tr. Eg.
	5	12	33	A. M.	I	Sh. In.
		1	34	"	I	Tr. In.
		2	45	"	I	Sh. Eg.
		3	45	"	I	Tr. Eg.
		8	36	P. M.	II	Ec. Re.
		9	44	"	I	Ec. Dis.
		11	19	"	III	Oc. Dis.
	6	12	32	A. M.	III	Oc. Re.
		12	53	"	I	Oc. Re.
		8	01	P. M.	I	Tr. In.
		9	14	"	I	Sh. Eg.
		10	12	"	I	Tr. Eg.
	10	12	30	A. M.	II	Ec. Dis.
	11	8	29	P. M.	II	Tr. In.
		9	00	"	II	Sh. Eg.
		10	44	"	II	Tr. Eg.
	12	2	27	A. M.	I	Sh. In.
		3	21	"	I	Tr. In.
		4	39	"	I	Sh. Eg.
		11	07	P. M.	III	Ec. Dis.
		11	38	"	I	Ec. Dis.
		12	37	"	III	Ec. Re.
	13	2	48	A. M.	I	Oc. Re.
		2	48	"	III	Oc. Dis.
		4	00	"	III	Oc. Re.
		8	55	P. M.	I	Sh. In.
		9	47	"	I	Tr. In.
		11	08	"	I	Sh. Eg.
		11	58	"	I	Tr. Eg.
	14	9	06	"	I	Oc. Re.
	17	3	05	A. M.	II	Ec. Dis.
	18	9	17	P. M.	II	Sh. In.
		10	49	"	II	Tr. In.
		11	37	"	II	Sh. Eg.
	19	1	04	A. M.	II	Tr. Eg.
		4	21	"	I	Sh. In.
	20	1	32	"	I	Ec. Dis.
		3	07	"	III	Ec. Dis.
		4	25	"	I	Oc. Re.
		4	37	"	III	Ec. Re.
		8	02	P. M.	II	Oc. Re.
		10	50	"	I	Sh. In.
		11	33	"	I	Tr. In.
	21	1	02	A. M.	I	Sh. Eg.
		1	44	"	I	Tr. Eg.
		8	01	P. M.	I	Ec. Dis.
		10	52	"	I	Oc. Re.
	22	7	30	"	I	Sh. Eg.
		8	10	"	I	Tr. Eg.
	23	7	00	"	III	Sh. Eg.
		8	07	"	III	Tr. In.
		9	20	"	III	Tr. Eg.
	25	11	53	"	II	Sh. In.
	26	1	06	A. M.	II	Tr. In.
		2	14	"	II	Sh. Eg.
			1		II	Tr. Eg.

Oct.	27	3	27	"	I	Ec.	Dis.			7	12	P. M.	I	Sh.	In.
		6	58	P. M.	II	Ec.	Dis.			7	43	"	I	Tr.	In.
		10	18	"	II	Oc.	Re.			9	24	"	I	Sh.	Eg.
	28	12	44	A. M.	I	Sh.	In.			9	54	"	I	Tr.	Eg.
		1	17	"	I	Tr.	In.		30	7	02	"	I	Oc.	Re.
		2	56	"	I	Sh.	Eg.			9	14	"	III	Sh.	In.
		3	28	"	I	Tr.	Eg.			11	00	"	III	Sh.	Eg.
		9	55	P. M.	I	Ec.	Dis.			11	20	"	III	Tr.	In.
	29	12	36	A. M.	I	Oc.	Re.		31	12	39	A. M.	III	Tr.	Eg.

Configuration of Jupiter's Satellites at Midnight Central Time.

Sept.						Sept.						Oct.					
1		1	4	○	2	3	22		1	○	2	3	4	11	☌	3	○	1	4
2			2	○	1	4	3	23			○	2	1	3	4	12		2	3	1	○	4	
3		2	1	3	○	4		24		2	1	○	3	4		13		☌	4	○	2	3	
4			3	○	1	2	4	25			3	○	1	4	●	14			4	○	1	2	3
5			3	○	2	4	●	26		3	1	○	4	2		15		4	2	1	○	3	
6		2	3	1	○	4		27		3	4	2	○	1		16		4	2	3	○	1	
7			2	○	1	3	4	28		4	2	○	1	3		17		4	3	1	○	2	
8			1	○	2	4	3	29		4	1	○		2	3	18			4	3	○	2	1
9			☌	○	4	1	3	30			4	○	2	1	3	19	4	2	3	1	○		
10	☌	2	4	1	○			Oct.								20				4	○	1	2	3
11			4	3	○	1	2	1		4	2	1	○	3		21				4	○	2	3	●
12			4	3	○	2	●	2		4	3	2	○	1		22			2	1	○	4	3	
13	4	3	2	1	○			3		3	4	1	○	2		23			2	3	○	1	4	
14			4	2	○	1	3	4		3	4	2	○	1		24			3	1	○	2	4	
15			4	1	○	2	3	5			2	3	○	4	●	25				3	○	2	1	4
16				4	○	2	1	3	6			1	○	2	3	4	26		2	3	1	○	4	
17		2	4	1	○	3		7				○	1	2	3	4	27					○	1	3	4	●
18				3	○	4	2	1	8		2	1	○	3	4		28					○	2	4	3	●
19			3	1	○	2	4	9			3	2	○	1	4	29				2	1	○	4	3	
20	☌	3	2	○	4			10			3	1	○	2	4	30		☌	2	4	○	1		
21			2	○	1	3	4									31			4	3	1	○	2		

Phases and Aspects of the Moon.

	d	h	m	
Apogee	Sept. 17	8	18	"
First Quarter	" 17	10	19	P. M.
Full Moon	" 25	2	23	"
Perigee	" 29	9	48	A. M.
Last Quarter	Oct. 2	9	19	"
New Moon	" 9	2	27	P. M.
Apogee	" 15	4	00	A. M.
First Quarter	" 17	5	20	P. M.
Full Moon	" 25	1	28	A. M.
Perigee	" 27	12	30	"
Last Quarter	" 31	4	42	P. M.

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T.		IMMERSION Angle f'm N pt.	EMERSION Washington M. T.		EMERSION Angle f'm N pt.	Duration	
			h	m	°	h	m	°	h	m
Sept. 23	74 Aquarii	6.0	7	39	39	8	52	255	1	13
24	24 Piscium	6.1	15	42	17	16	31	276	0	49
28	δ Arietis	4.0	8	26	63	9	19	243	0	53
28	τ^1 Arietis	5.0	13	32	34	14	41	265	1	09
Oct. 1	49 Aurigæ	5.7	15	17	113	16	28	241	1	11
2	ν Geminorum	4.3	14	03	35	14	39	327	0	36
17	b Sagittarii	4.6	5	06	134	5	53	194	0	47
20	56 Aquarii	6.3	5	41	82	6	55	213	1	14
21	ψ^1 Aquarii	4.1	3	58	80	5	01	224	1	03
23	ζ Piscium	4.8	16	42	44	17	33	266	0	51
26	36 Tauri	6.0	15	48	105	16	51	227	1	03

COMET NOTES.

There are no comets known to be visible with small telescopes at the time of this writing, and in fact it is doubtful whether any will be visible in the large telescopes by the time this number of POPULAR ASTRONOMY reaches our readers. The last discovered comet, *b* 1893, commonly named after two independent discoverers, Rordame-Quenisset, is rapidly receding from the Earth and Sun, and at the same time being hidden in the evening twilight.

It is an interesting fact that this comet was observed by Mr. W. E. Sperra, an amateur astronomer of Randolph, Ohio, for over two weeks before it was discovered by Rordame. The former mistook the new comet for Finlay's periodic comet on June 20, when it was in Right Ascension $2^h\,43^m$, Declination 17° 30′ N. and observed it on eleven nights before July 8. Not having at hand an ephemeris of Finlay's comet covering that period of time, he did not find out his mistake until it was too late to claim the honor of discovery.

Comet b 1893.—This comet was first noticed at this place by me about 9:30 P. M., July 7th, appearing as a large, hazy star without visible tail, but its true nature was not then suspected. My first telescopic observations were obtained on July 9th, when the comet was a fine object in my 3-inch glass, the coma was large and bright with a strong central condensation; for about 4 or 5 degrees from the "head" the train was fully as bright as the coma and well defined at the edges, from thence it faded gradually but could be traced curving slightly to the N. N. E. for a distance of about 15 degrees; a minute tail was suspected on the east side of the coma close to the main train.

July 10th: The train could be traced for only about 12 degrees to-night, it is wider and less bright and not as well defined at the edges near the head, the coma also does not appear as distinct as on last evening. 11th: Appearance about the same as last night, train could be traced about 17 degrees. 12th: The comet is much more distinct to-night, the coma is brighter and apparently slightly oval, and nucleus quite bright, train about 22 degrees in length. 13th: Train appears much shorter and narrower and is somewhat fainter, coma also appears smaller and the nucleus very stellar, train about 13 degrees. 14th: Train very faint and difficult with the naked eye being visible for only about 5 degrees, coma about the same as on last evening but nucleus seems more stellar. 17th: Train faint about 3 degrees in length. At 11 P. M. a minute condensation of light was detected about ½° from the coma which proved to be a small star when it emerged from behind the tail, it appeared very diffused seen through the tail. 18th: The comet is much brighter to-night than it has been for several nights, the train is more defined for a longer distance even with the strong moonlight. 19th: Coma decreasing, train could be traced only about 1°. 25th: Coma bright with apparently larger nucleus which did not appear stellar. 28th: Coma bright, faint tail only about ½° long, no bright nucleus could be seen. August 3d: Nucleus decidedly stellar, comet is now only about ⅓ degree long, but still a conspicuous object in 3-inch telescope. Aug. 13th: Comet is much smaller and appears somewhat elongated although no train or nucleus could with certainty be seen.

As far as my observations go the comet appeared at its best as regards brightness and distinctness of coma and a portion of train on the evening of July 9th, while the train reached its maximum length, about 22°, on the 12th.

DAVID E. HADDEN.

Alta, Iowa, August 16th, 1893.

GENERAL NOTES.

This number was delayed a few days more than anticipated because the engraving work was behind time. We expect the second number will be mailed on or before October 5th.

The general articles for this issue are largely introductory, but they well suggest the plan of this popular magazine, and, we believe, will tend to bring the scholars and the popular readers of astronomy nearer together in common interest.

This part of our publication will be open to appropriate questions and brief answers. Send them in early each month, so that there shall be time for best answers to queries and comparison of views of competent authority when desirable. Here is an example: "Where is the international date line?" This can best be answered, probably, by a small hemisphere map, showing its position from the Arctic ocean, north of Bhering Straits, in irregular course, till it reaches the Antarctic ocean. We will try to give such a map next time.

Constellation Study.—Professor Winslow Upton, the writer of the first article, is the director of the Ladd Observatory, Brown University, Providence, R. I. He studied practical astronomy at Cincinnati Observatory, was afterwards connected with the government signal service at Washington, and later was called to his present position. Read the introduction to his series of articles on constellation study, and notice every point of suggestion carefully. Interested students will seize this opportunity for self-instruction, and lose nothing through lack of personal and vigorous application in nightly half-hour studies.

The Spectroscope and Some of its Applications.—The spectroscope is now recognized as so indispensible an instrument in the study of modern astronomy, that the average popular reader should understand its elemental principles and its applications. These are so simple that a teacher or student may master them thoroughly in a short time if the needed information is within reach. Professor James E. Keeler, the director of the Observatory at the Western University of Pennsylvania, Allegheny City, has kindly promised to furnish this in a series of articles on the above named topic. He was formerly assistant to Professor S. P. Langley, in that Observatory; was later appointed astronomer at Lick Observatory, where he did work of world-wide fame with the spectroscope, and, finally, he was recalled to the directorship of the Allegheny Observatory. This series of articles will explain the spectroscope and its wonderful work in late years, we are sure, in most admirable way.

Study of the Moon.—Foreign observers are doing more than those in America at present in the study of the Moon. For aid in this work we have asked T. G. Elger and others. Mr. Elger is a Fellow of the Royal Astronomical Society, and the director of the observing section for lunar study of the British Astronomical Association. By this means we hope to present, in clear and satisfactory way, problems now under astronomical study concerning our nearest neighbor. The photogravure copies of photographs shown in our frontispiece

will interest readers generally, because the upper plate is by an 8¼-inch telescope, while the other was taken by the aid of the great Lick refractor of 36-inch aperture. Any one who has either Neison, or Nasmyth and Carpenter, on the Moon, will find good exercise in recognizing scores of surface markings plainly shown in both. Try it.

As a simple exercise for the inexperienced try to recognize markings on the Moon's surface by the aid of the naked eye only. How many objects can be *distinctly* seen? Make a picture of what can be seen whether the names are known or not. Try again and see if more can be observed *certainly*. Use an opera glass and notice how many more objects can be added. Why does the observer see more now? Does he see as much more as he ought, considering the diameter of the pupil of the eye as compared with that of the field lens of the opera glass? Many useful easy lessons might be suggested.

Double Star Astronomy.—S. W. Burnham of Chicago, late of the Lick Observatory staff, is, without doubt, the ablest scholar in double star astronomy in the world. It is gratifying to announce that he will write for this magazine on his favorite theme in a way to help those who have small telescopes and want to learn how to do useful work in this most interesting field of research. He will present an article in our next issue.

Making Telescopes and the Care of Them.—We are glad to announce that J. A. Brashear, one of the foremost opticians in the United States, will prepare a series of articles for POPULAR ASTRONOMY on the making of telescopes and how to care for them. Mr. Brashear's reputation fairly authorizes him to write for professional astronomers in such matters, but he now proposes to prepare something for amateurs particularly.

Shooting Stars—How to observe them and what they teach us.—W. F. Denning, Bishopston, Bristol, England, has generously consented to furnish articles for us concerning the Shooting Stars, how to observe them and what they teach us. Mr. Denning's long experience in observing these peculiar phenomena and his thorough study of the radiants of a great number of different streams of meteors, enable him to speak of details for the professional astronomer with recognized authority. Amateurs will certainly find his articles abundantly helpful. They will begin in our next number.

E. E. Barnard of the Lick Observatory will begin in our next, a series of articles on Celestial Photography. He has recently returned from an extended visit to the astronomical observatories of Europe. His photographs of portions of the Milky Way and other celestial objects were exhibited at a meeting of the Royal Astronomical Society of England, June 9 of this year, and by the hearty vote of thanks given him at its close, it is evident that Mr. Barnard's photographic work pleased the distinguished English astronomers present. The more important of these excellent photographs will appear later in one or the other of our astronomical periodicals. The wants of amateurs with small lenses will be kept in mind constantly.

Miss Eliza A. Bowen's excellent article on the Harvest Moon, elsewhere given, is an illustration of how admirably she can put ideas into language. The

attention of teachers in the elements of astronomy is called to that paper. Her direct and simple way of putting a matter that often puzzles students, we are sure, will be regarded with favor. Other good things from her ready pen will follow. Those who have seen her popular work entitled "Astronomy by Observation," published by D. Appleton & Co., New York, are already favorably advised of the writer's reputation.

Dr. Lewis Swift will contribute articles on comet-seeking and the nebulæ. It is somewhat generally known that Dr. Swift himself owns one of the best large telescopes in the United States. It is a Clark 16-inch glass and with it he has discovered a very large number of new nebulæ. Dr. Swift's work in discovering comets was done, however, years ago by the aid of a small telescope. He is greatly interested in amateurs and their work. He will probably continue observing work at Rochester, N. Y., for a while yet, although it was decided a few months ago to remove his Observatory to some point on the Rocky Mountains.

Dr. H. C. Wilson of Goodsell Observatory will write on various topics. He has had excellent opportunity for study and observation with the best of American Astronomers. The editorial work done in *Astronomy and Astro-Physics* for the last two years is certainly suggestive of what may be expected for POPULAR ASTRONOMY from Dr. Wilson's pen. He will continue to prepare the planet tables and aid in planet and comet notes. The tables and planet notes are the only matter that will appear unchanged in both magazines. They will consist of four or five pages each month.

Personal Sketches.—Another feature of popular interest is under consideration. It has seemed to us that our readers would be helped, if we could furnish from month to month good half or third page pictures of eminent scholars or observers in astronomy. The sketch to accompany the illustration should be very brief, not to exceed a page of printed matter. The object of this is to familiarize interested readers with the living men and women who lead in opinion and ability in astronomy. Other lines of publication do this creditably, why is this one an exception? Of course every person so represented should see and pass judgment on all that is to be published before it appears, to avoid all error of statement or other unfavorable representation.

Professor George E. Hale, director of the new Yerke's Observatory of the University of Chicago, has promised to write some popular papers on the Sun. His recent wonderful discoveries in regard to photographing the faculæ and solar prominences, so called, place him among the first of American Astronomers in regard to stellar and solar physics. Reference is made to Volumes X and XI of *Astronomy and Astro-Physics* for details of information and beautiful photogravure illustration of both faculæ and prominences, as photographed by Professor Hale's new method. In this our readers will have the newest of the new astronomy in solar studies.

Division of Work.—Text-books, maps, charts and general courses of reading in astronomy are all good and useful in their respective places, but they are by no means all that is necessary or desirable to put a person at his best for ac-

quiring general knowledge in this branch. We have so often seen the good results of division of work and associated study that we are ready to recommend it heartily under proper guidance. Why would it not be a good plan in any small village or in connection with any high school to form a class of half a dozen or more young people for the sake of reading the elements of astronomy and such observational study of the face of the sky as can be done by the naked eye and the opera glass. One of the best maps of the Milky Way we have ever seen was made from naked eye observation alone. A great deal of useful and enjoyable study can be done with the unaided eye, if a person has any interest in such things. We suggest the plan of classified, associate study. For example, those persons who wish to begin the study of the Moon, send us their names indicating what they have done, if anything, whether or not they have any telescope; if so, its size, maker, and attachments, as eyepieces, micrometer, clock, spectroscope, etc. In the same way in regard to the following subjects: Meteors, Star Colors, Variable stars, Jupiter, Sun and others in observational and reading courses. If this is done to any considerable extent, we will undertake the classification and try to secure a competent and experienced guide for each class that can use about the same grade of work on a given topic. We believe work like this is the secret of the interest and success of so many amateur astronomical societies that have recently formed in many parts of the United States. The rapid growth and usefulness of some of these societies is simply phenomenal. This is a part of the great university extension work everywhere so popular. It ought to be extended even more widely. Very general correspondence is solicited concerning this specialized, associated study and observation.

Poole Brothers' Celestial Hand-book is intended as a companion to their Celestial Planisphere, a description of which is found among the advertisements of this issue.

Mr. Jules A. Colas, the editor and compiler of this hand-book, is a scholarly gentleman, and he has taken great pains to collect and arrange within the compass of 110 pages a large amount of material to accompany the planisphere before referred to. We have used the planisphere and hand-book considerably, and have found them both excellent so for as we have been able to examine them carefully. For most of the numerical values given the authority is named, so that it is easy to verify them. The illustration is ample and very good in kind. We notice 140 cuts in the space of the 110 pages. The reading matter is in small type and the printing is superb. We doubt if so much, in so limited space, can be found elsewhere, if we take into the account the amount and variety of illustration. It is a pleasure to call attention to this new work.

Publisher's Notices.—The subscription price for POPULAR ASTRONOMY is $2.50 per year, foreign countries 14 shillings, payable in advance, the annual volume consisting of ten numbers, issued monthly, except for July and August, each containing at least 48 pages of reading matter. Articles for publication may be sent to Wm. W. Payne, Goodsell Observatory, Carleton College, Northfield, Minn., or to Miss C. R. Willard, same address. All remittances for subscription or advertising should be sent to Miss Willard who is in charge of the accounts of the office.

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